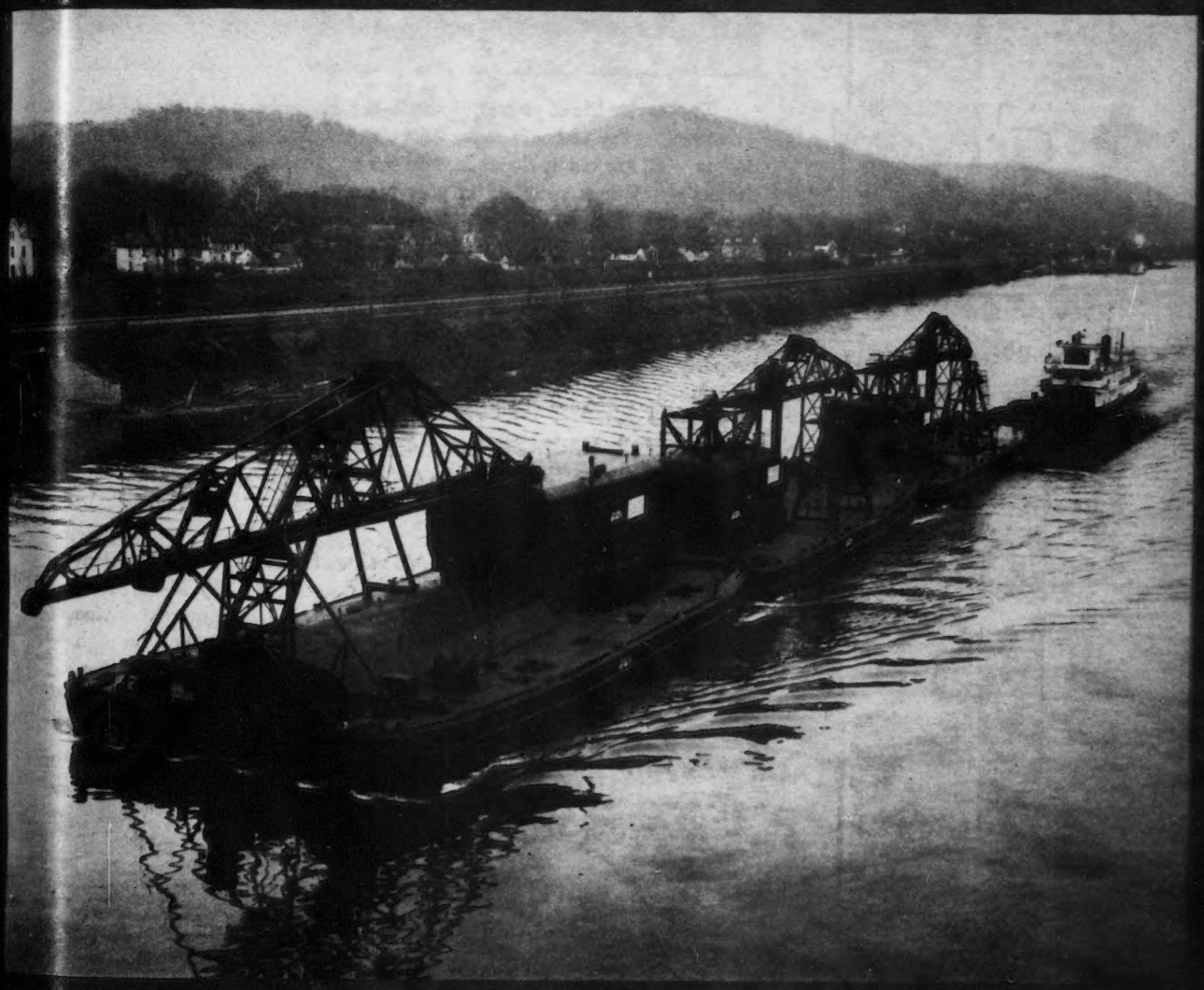
# Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



JANUARY 1954

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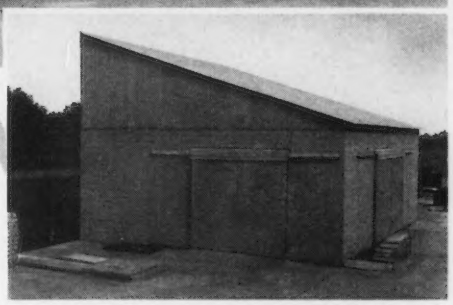
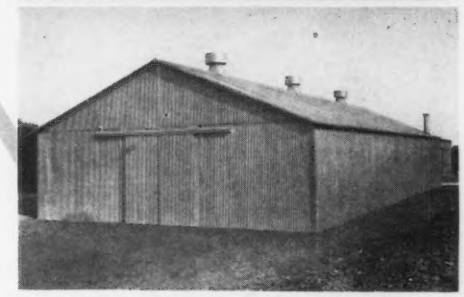


**SMELTER**

This uniquely designed steel and concrete block building contains two 4000 lb. magnesium smelting furnaces capable of smelting and alloying 50 tons of metal weekly. Anodes are cast direct from spectrographically analyzed heats of hi-purity magnesium metal.



**WAREHOUSE & PACKAGING PLANT**

This steel building houses our warehouse and packaging facilities. Chemicals used in the packaging of anodes are screened and stored according to the granular specification required in packaging. Here lead wires are attached to anodes. The anodes are then conveyed to our specially designed mixer, where they are scientifically Vibra-Pak'd with a predetermined mixture of chemical backfill.

**OFFICE & LABORATORY**

This building houses our offices and modern spectrograph laboratory. The spectrographic laboratory equipment is of the most modern design and is capable of analyzing element quantities of less than 1/10,000 of 1%.

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TULSA, OKLAHOMA

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When you plan your next pipeline protection job, figure it *two ways* . . . one with Galvo-Line. Let the facts prove themselves. THE DOW CHEMICAL COMPANY, Midland, Michigan.

*you can depend on DOW MAGNESIUM ANODES*

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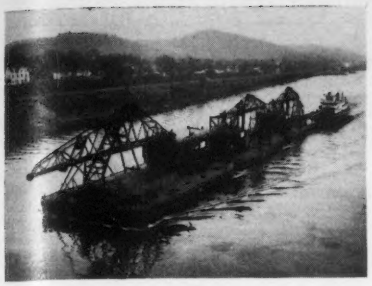

THIS MONTH'S COVER—Two 60-ton and one 100-ton floating cranes are shown here being towed to a government storage basin. The cranes have been protected against corrosion during storage by Dravo Corp., Pittsburgh, by various means, including coatings, coverings and dehumidification. More details of the methods used are given in the Topic of the Month, Page 1, News Section, this issue.

☆


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## NEWS REPORTS FOR CORROSION

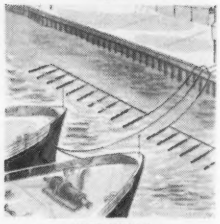
News reports on activities of regions, sections and other subdivisions of the National Association of Corrosion Engineers should reach Central Office NACE before the tenth of the month preceding the month in which the report is to be published.

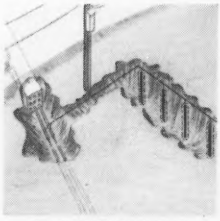
- Secretaries who do not already have a supply are invited to ask for copies of the form "News Report for Corrosion" which facilitates making reports on meetings. Notices of future meetings will be carried in the "NACE Calendar" in the News Section when information is provided in time.
- News of meetings of corrosion interest of whatever origin are welcomed and will be carried when space permits.

# NATIONAL TRADE-MARK GROUND ANODES GIVE *PERMANENT* Cathodic Protection

There can be no doubt as to the effectiveness of cathodic protection in today's fight against corrosion of buried or submerged metal structures. But how *permanent* is the protective system itself? Impressed current systems, using **"National" graphite ground anodes,** give more positive, flexible, trouble-free and *lasting* protection than any other type.

MANY "NATIONAL" GROUND-ROD INSTALLATIONS ARE 20 YEARS OLD AND STILL GOING STRONG! Put in "National" ground anodes and they're there to stay. One look at the rectifier gives you top-side evidence that they're working—how much current they're discharging and at what voltage. Consult National Carbon Company or one of the many engineering firms specializing in corrosion prevention. Discover this *modern* way to combat one of industry's most costly enemies.


SHIP HULLS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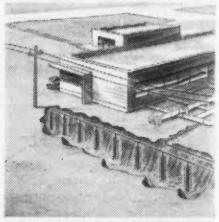
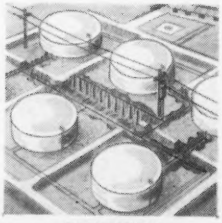
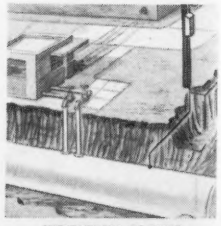

PIPE-LINE BOOSTER STATIONS


TANK FARMS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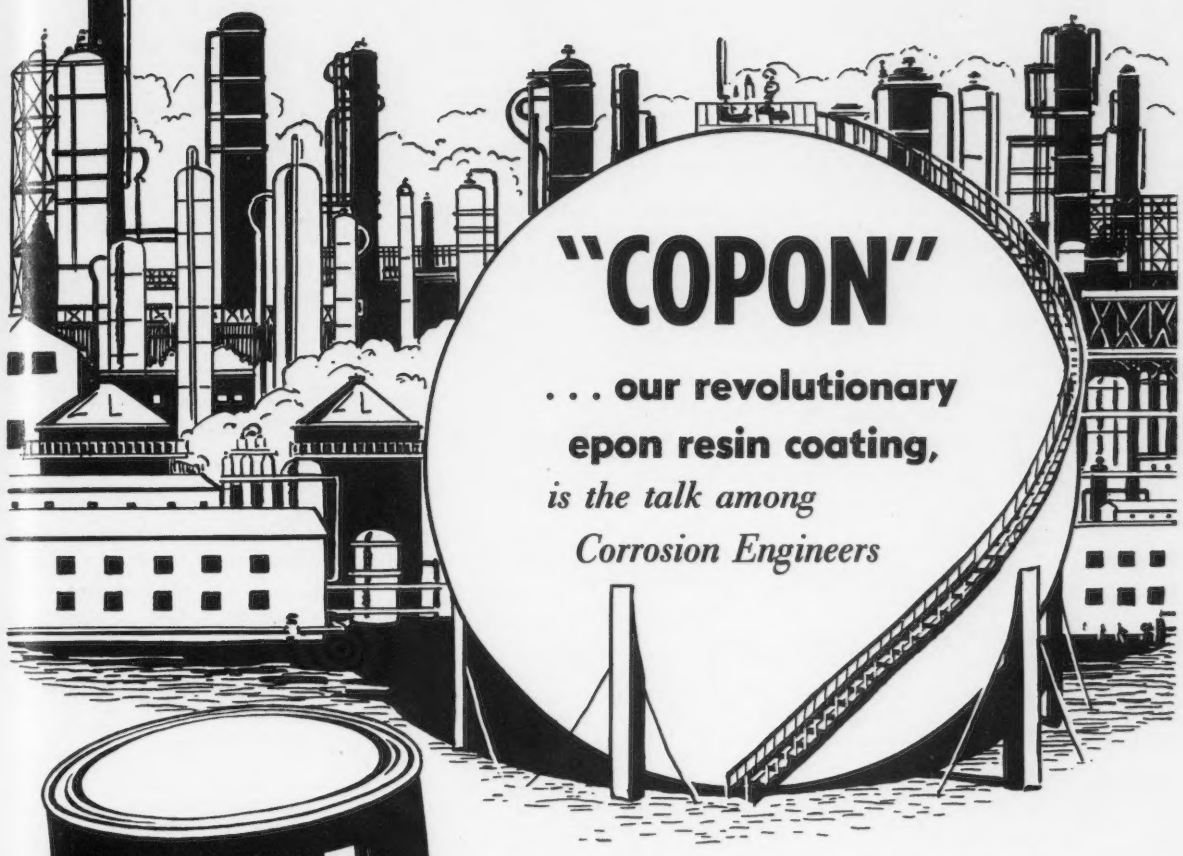

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See Page 1, Technical Section this issue for a statement concerning the reorganization of the NACE Technical Practices Committees and a table showing how the new and the old committees are related.

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Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

*Anode folders or technical consultation with our engineers available upon request.*

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means CORROSION PREVENTED!

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Here are the facts!

- DEL Coatings protect metal, masonry, wood against acids, alkalies, water, oils, weather, high heat, abrasion.
- Independent case histories prove DEL superiority.
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with DEL formulations of VINYLS, ACRYLICS, SYNTHETIC RUBBER, EPONS, SILICONES, PHENOLICS and other plastic resins — plus — DEL's amazing new SYNTHETIC RUBBER CAULKING COMPOUND.

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# NEW PROTECTIVE COATING CHEMICAL FOR ALUMINUM

## ALODIZING

Alodizing with "Alodine,"* a new technique in the protective coating of aluminum, was made available for production-scale use in 1946. Since that time Alodizing has largely supplanted the more elaborate, costly and time-consuming anodic treatments in the aircraft and other industries.

Continuous and successful industrial use has clearly demonstrated the simplicity and economy of the Alodizing process as well as the effectiveness of the "Alodine" amorphous coatings, particularly as a base for paint. In fact, the paint-bond that Alodized aluminum provides has been found to be superior to that possible with chromic acid anodizing.

The corrosion-resistance of unpainted aluminum Alodized with "Alodine" Nos. 100 or 300 is excellent, easily meeting the requirements of Specification MIL-C-5541. However, a need for protection of unpainted aluminum, even better than that obtained with chromic acid anodizing, has long been recognized.

## NEW IMPROVED "ALODINE" DEVELOPED By ACP RESEARCH CHEMISTS

Several years of intensive research have now led to a new type of "Alodine," designated as "Alodine" No. 1200. This new protective coating chemical forms an amorphous mixed metallic oxide coating of low dielectric resistance that provides unusually high corrosion-resistance for unpainted aluminum. In addition, it forms an excellent paint bond that approaches closely the high quality obtained with the earlier types of "Alodine."

After having been tested for conformance with Specification MIL-C-5541, "Alodine" No. 1200 is now about to go into production.

## PROCESS DETAILS

"Alodine" No. 1200 is the only essential chemical needed to prepare the coating bath and the final rinse bath. One of its unique features is that it can be used in tanks in an immersion process, or, in a multi-stage power washer in a spray process, or, with a slight adjustment of pH, with brush or portable spray equipment in a manual process. This means that even where the simple production equipment is not available, or where touching up of damaged coatings previously Alodized or anodized is required, excellent protection and paint bonding can still be obtained with practically no equipment.

All three methods of application easily meet the requirements of Specification MIL-C-5541.

Process sequence for all three methods of application is the same as for other standard grades of "Alodine" such as Nos. 100, 300, and 600, viz.: 1. Pre-cleaning. 2. Rinsing. 3. Alodizing. 4. Rinsing. 5. Acidulated rinsing. 6. Drying.

Coating time in an immersion process ranges from 2 to 8 minutes and in a mechanized spray process is about 30 seconds. "Alodine" No. 1200 baths are operated at room temperatures (70° to 100°F.) and heating is required only if the bath has gotten cold after a "down" period.

## RECOMMENDED USES FOR "ALODINE" No. 1200

"Alodine" No. 1200 is specifically recommended for coating wrought products that are not to be painted or are to be only partially painted; and for coating casting and forging alloys whether or not these are to be painted. "Alodine" Nos. 100 and 300 are still recommended for coating wrought products such as venetian blind slats, awnings, etc., that are invariably painted.

### RESULTS OF TENSILE TESTS

This new "Alodine" not only retards visible corrosion and pitting, but as shown in the table below, the loss of ductility with "Alodine" No. 1200, both brush and dip, after 1000 hours salt spray was less than for chromic acid anodizing after 250 hours, and for "Alodine" No. 100 and a conventional chromate treatment after 168 hours exposure.

| PROCESS | SALT SPRAY EXPOSURE | COMPLIANCE WITH TENSILE REQUIREMENTS OF MIL-C-5541 |
|---|---|---|
| CHROMIC ACID ANODIZING | 168 hrs. | passes |
| | 250 hrs. | passes |
| | 500 hrs. | fails |
| | 1000 hrs. | fails |
| BRUSH "ALODINE" No. 1200 | 168 hrs. | passes |
| | 250 hrs. | passes |
| | 500 hrs. | passes |
| | 1000 hrs. | passes |
| DIP "ALODINE" No. 1200 | 168 hrs. | passes |
| | 250 hrs. | passes |
| | 500 hrs. | passes |
| | 1000 hrs. | passes |
| DIP "ALODINE" No. 100 | 168 hrs. | passes |
| | 250 hrs. | fails |
| | 500 hrs. | fails |
| | 1000 hrs. | fails |
| CONVENTIONAL CHROMATE TREATMENT | 168 hrs. | passes |
| | 250 hrs. | fails |
| | 500 hrs. | fails |
| | 1000 hrs. | fails |

*"Alodine" Trade Mark Reg. U. S. Pat. Off.

CHEMICALS ACP PROCESSES

**AMERICAN CHEMICAL PAINT COMPANY**

**General Offices: Ambler, Penna.**

**Detroit, Michigan** **Niles, California** **Windsor, Ontario**

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## For Lining Tanks

### Here's why

**TYGON's** outstanding resistance to acids and alkalies permits its use in all the usual lining and covering jobs.

**TYGON's** unique resistance to oxidizing acids, oils, greases, and solvents makes possible its use in jobs other linings cannot handle.

**TYGON's** flexibility permits close conformance, resulting in a good bond, to all but the most intricately shaped equipment.

**TYGON's** resilience minimizes the possibility of damage from mechanical abuse.

**TYGON's** elasticity permits thermal contraction and expansion without rupture.

**TYGON's** abrasion resistance withstands the wearing action of thick slurries and dry or moist chemicals.

**TYGON's** negligible extractibility prevents contamination of the most sensitive solutions.

**TYGON's** availability in white (compound TL-104), as well as standard black, permits its use where solution visibility is highly important.

**TYGON's** high electrical resistivity prevents current losses in electrolytic action.

**TYGON's** smooth, non-porous surface makes for easier cleaning and greater solution flow.

**TYGON's** thermoplasticity permits the "heat-sealing" of seams to form continuous, one-piece, impermeable linings.

**TYGON's** selective solvent sensitivity eliminates the "need" for curing to obtain a strong bond — makes possible installations of virtually any size — simplifies field repairs.

**TYGON's** non-oxidizing characteristics give it a long service life.

And remember, Tygon linings can be installed by a licensed Tygon applicator near you—with major savings in time and money.

*Write, right now, for more information! Ask for our new 12-page booklet on TYGON LININGS— Bulletin TL-526. It's packed with facts and figures.*

**LICENSED TYGON APPLICATOR**

**U. S. STONEWARE**

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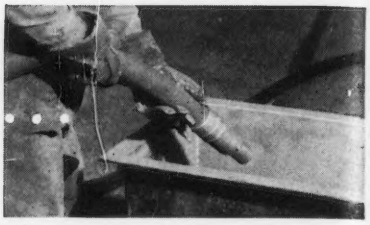
**PROCESS EQUIPMENT DIVISION**

158-D

### Here's how

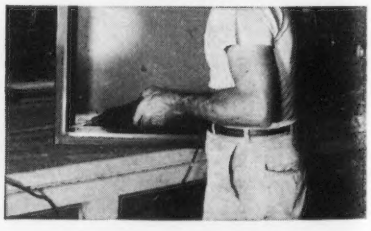


The tank is carefully sand-blasted before lining.

Special cements that bond without vulcanizing are used.

Thick TYGON plastic sheeting is applied.

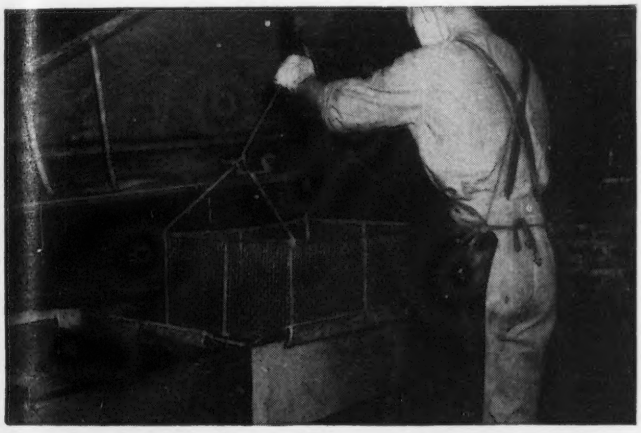
Joints are "strip-sealed" to make a one-piece impervious membrane.



The entire Tygon lining is carefully "spark-tested."

# Why Pickle the Equipment Too?

**ALLOY TRAYS SAVE $1600 A YEAR**—Pickling trays made of HASTELLOY alloy C have saved a company $1600 a year. The trays are immersed in hot 20 per cent hydrochloric acid and then into a solution of one per cent phosphoric acid with ferric salts at 205 deg. F. This treatment is used to produce a porous surface on metal parts. HASTELLOY alloy trays last two years. Other trays lasted only two months.



**SIX YEARS IN HOT HCl**—This HASTELLOY alloy B pickling tank has already outlasted other materials by four times. It is expected to be good for many years to come. The tank holds hot 15 per cent hydrochloric acid used to remove grease and lacquer from cast iron parts.

**VAT PAYS FOR ITSELF**—Here's a HASTELLOY alloy C vat that has already paid for itself and is still going strong. It is used to pickle copper parts in a mixture of 30 per cent nitric acid and 60 per cent sulphuric acid at 180 to 200 deg. F. Crocks previously used had to be replaced on an average of every six months.

•

HASTELLOY *alloys can solve some of your corrosion problems, too. For further information, contact the nearest Haynes Stellite Company office listed below.*

"Hastelloy" is a registered trade-mark of Union Carbide and Carbon Corporation.

**HASTELLOY** *alloys*
Trade-Mark

Nickel-base, corrosion-resistant alloys available as sheet, plate, bar stock, welding rod, welded tubing and pipe, cast pipe and fittings, sand and precision-investment castings.

**Haynes Stellite Company**
**A Division of**
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UNICHROME
Trade Mark

*News about*
# COATINGS for METALS
*Metallic . . . . . Organic . . . . . Decorative . . . . . Protective*

# How to benefit most from modern coatings

## HOW SPECIAL VINYL COATINGS PROLONGED PUMP LIFE

Centrifugal pumps moving salt water for a processing plant were being replaced every 12 to 18 months because of erosion and corrosion of impeller and housing. Then impellers were coated with 30 mils of a vinyl Unichrome Plastisol Compound, the housings with 5 mils of an unusual vinyl Ucilon Coating System. After one year, inspection showed the coatings and pumps still in excellent condition.

This case illustrates the heavy duty protection given to metals by extra tough, resilient Unichrome Plastisols and Ucilon Protective Coatings. Applied by dipping or spraying, Unichrome Plastisols provide films from .003" to 3/16" thick. Do you have use for such a coating? Write us the details.

## *Vinyl drum lining resists many chemicals*

There's no such thing as a "universal" drum lining – one usable with *all* types of chemicals. But there *is*, however, a Unichrome vinyl-type coating that withstands an unusually large group of them.

That's why Unichrome B-154 Lining was recommended to a chemical processor who was producing a variety of compounds and searching for a single lining to resist all. This coating was found to fill the bill – having withstood a full year of testing in contact with organic sequestering agents, sulfonated oils and textile finishing agents.

For drum lining data, send for Bulletin DL-1.

UNICHROME
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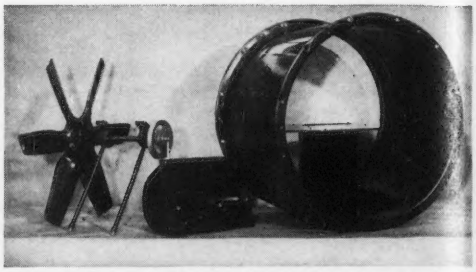
## Unusual service life assured when Ucilon* Protective Coating Systems are specified as original-equipment-finish to meet corrosive conditions . . . and for maintenance, too.

Equipment designed for industrial use often encounters conditions so corrosive that ordinary finishes give short lived protection. What then? The maintenance engineer has to discover, often at considerable effort, protective coatings that *can* resist the strong corrosives; and then apply these to the surfaces which, at considerable extra expense, have again had to be adequately prepared for the refinishing.

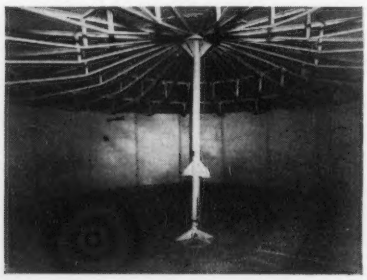


New equipment to be in contact with corrosive fumes is better equipped for service with Ucilon Coating protection.

Systems of Ucilon Protective Coatings are being selected by many chemical, corrosion and research engineers for this job on the basis of their proved durability; also their resistance to strong acids, alkalies, salt solutions, alcohols, oils or other finish-destroying compounds.

### PROTECTION SHOULD START WITH ORIGINAL FINISH

It stands to reason that if a coating system proves its worth when used for *maintenance*, it will prove even more worthwhile when used as the *original* finish. Thus, because of the unusually long protection obtained when Ucilon Coatings are applied to maintain equipment against corrosion-damage, more and more companies are now beginning to specify these coatings right from the start for *new* equipment. This not only improves the product functionally, but also simplifies subsequent maintenance.



Interior of large brine tank for which Ucilon Protective Coating System was specified.

### PROTECT AGAINST FUMES, CHEMICALS OR WATER

A great majority of coating problems arise from such conditions as continuous or intermittent contact with fumes, chemical solutions or water. Systems of Ucilon Coatings developed to combat these primary causes of coating failure include vinyl, phenolic, chlorinated rubber and fish oil formulations. Sixteen systems of Ucilon Coatings now exist which afford the needed protection and durability against over a hundred corrosives. A "system" may include special primers and intercoats in addition to a specific number of topcoats.

### QUICK PICTURE OF RESULTS

Interior of brine tanks still protected 5 years after application of Ucilon Coating System . . . 5 years' service obtained against HCL fumes with virtually no patchwork of the Ucilon Coatings needed . . . No failure observed after almost two years of Ucilon Coating protecting tank car carrying saturated ammonium nitrate solution . . . Even after 3 years, no deterioration seen in Ucilon Coatings on steel submerged in sewage.

### CONCLUSIONS

To get the most benefit from today's protective coatings, (1) determine what corrosives must be combatted; (2) select a Ucilon Coating System recommended for the conditions; (3) specify it for any new equipment to be installed; (4) apply it on present equipment and structural surfaces for longer lasting protection and to reduce frequency of "painting." Write for bulletin MC-7. **Trade Mark*

# You buy steel by specifications...

## ...be sure you know your Pipeline Enamel "Specs"

You wouldn't think of buying steel, pumps or other similar items without seeing written specifications that tell you exactly what you're getting for your money. Then why shouldn't you buy *pipeline enamels* in exactly the same way? Why not compare enamels, specification by specification, and insist that the enamel you buy stays within those written specifications?

Published specifications of *Pitt Chem* Modified, Standard and Plasticized Enamel are available and will gladly be sent on request. Samples, too. We invite you to test the softening point, ash, penetration, and other important specifications of Pitt Chem Enamel. You'll prove to your own satisfaction that coal-to-enamel quality-control definitely does produce a true-to-specification coating that gives you better performance above ground and longer-lasting protection below.

★ Standard Grade Tar Base Enamel
★ Modified Grade Tar Base Enamel
★ Plasticized Grade Tar Base Enamel
★ Cold Applied Tar Base Coatings

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# THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 10 January, 1954 No. 1

# Reorganization of the Technical Practices Committee

By H. W. SCHMIDT, Chairman*

THE TECHNICAL Practices Committees of the National Association of Corrosion Engineers were organized about eight years ago, although the forerunner group. Technical Practices Committee 1 on Condensate Well Corrosion, was formed two years earlier. New committees were added from time to time until they numbered 19 covering a wide variety of interests. Concurrent with this rapid growth it became evident that some procedure of uniform conduct was essential to facilitate control. The need for a procedure guide was emphasized by the fact the chairman of the committee was being involved in a greater and greater burden of detail and was required to make many important decisions single handed.

Since the 1953 annual NACE meeting in Chicago a group composed of W. F. Rogers, Aaron Wachter, A. B. Campbell and H. W. Schmidt has actively considered a number of proposals concerning reorganization of the technical committees. The Technical Practices Committee Organization and Procedures Manual, published in this issue of CORROSION** is the result of this group's deliberations. The reorganization plan, also published in this issue, was developed from the provisions of the manual. Both the manual and the reorganization have been approved by the NACE board of directors.

Reorganization of the committees and the provisions of the procedures manual become effective on March 18, 1954. It is believed these changes will eliminate many of the difficulties formerly experienced because responsibilities are delegated and adequate control is established. Provision has been made for changes required for effective functioning.

The manual outlines in detail the organization and functioning of the technical committees and the reorganization plan shows how the committees are related to one another and what redistribution has been effected.

It was recognized that many plans were feasible. The plan approved was based on NACE experience that most success has been enjoyed when a committee worked within an industry. This facilitated cooperation and accomplishment owing to strong common interest in specific corrosion problems such as is encountered in oil and gas production, pipe line, utilities, process industries and others.

New organizational subdivisions and their line of communication is Technical Practices Committee <—> Technical Group Committee <—> Unit Committee <—> Task Group. There is only one Technical Practices Committee. Technical Group Committees are now six in number for various broad industry interests. This number may be increased as needed. There is no limit to the number of Unit Committees or Task Groups which may be established.

The Technical Practices Committee is a policy making group composed of a chairman and vice-chairman, the vice-president of NACE and the chairmen of the six Technical Group Committees. The president of NACE is an ex officio member. The Technical Practices Committee will coordinate activities and functions of all technical committees and act on policy and planning matters affecting them. It is responsible to the board of directors through its chairman.

The Technical Group Committees are the policy and planning committees for industries. Actual technical work will be done by Unit Committees and Task Groups. As many working committees may be formed as necessary.

Lines of communication are established within the structure and provisions made for elections of officers, establishment of new committees, approval of technical reports, terminations of committees and other matters. A uniform method of conducting committee business is available now. The new designation "T" for technical will differentiate the new groups from the old.

There were 19 TP committees under the old organization. To form the new Technical Group Committees, several of the old TP committees with the same industry interest were grouped. None of the old committees was eliminated. To illustrate: The new Technical Group Committee T-2 (Pipe Line Corrosion) is composed of old TP-2, 3, 4, 17 and 18. Each of the old committees will retain

(Continued on Page 2)

* The Dow Chemical Company, Midland, Mich.
** See Page 14, News Section, this issue.

## TECHNICAL COMMITTEES

| New ← DESIGNATIONS → Old | |
|---|---|
| **T-1.** | **Corrosion in Oil and Gas Well Equipment** — TP-1 |
| T-1B. | Condensate Well Corrosion — TP-1B |
| T-1C. | Sweet Oil Well Corrosion — TP-1C |
| T-1D. | Sour Oil Well Corrosion — TP-1D |
| T-1F. | Metallurgy — TP-1F |
| T-1G. | Sulfide Stress Corrosion Cracking — TP-1G |
| T-1H. | Oil String Casing Corrosion — TP-1H |
| T-1J. | Oil Field Structural Plastics — TP-1J |
| T-1K. | Inhibitors for Oil and Gas Wells — TP-1K |
| | T-1K-1. Pacific Coast Region — TP-1A |
| T-1L. | Waste Water Disposal |
| | T-1L-1. Pacific Coast Region — TP-1A |
| **T-2.** | **Pipe Line Corrosion** |
| T-2A. | Galvanic Anodes — TP-2 |
| | T-2A-1. Galvanic Anode Operating Installations — TP-2A |
| T-2B. | Anodes for Impressed Currents — TP-3 |
| T-2C. | Minimum Current Requirements — TP-4 |
| T-2D. | Standardization of Procedures for Measuring Pipe Coating Conductance — TP-17 |
| T-2E. | Petroleum Products |
| | T-2E-1. Internal Corrosion of Product Pipe Lines and Tanks — TP-18B |
| T-2F. | Sour Crude Oil |
| | T-2F-1. Internal Corrosion of Crude Oil Pipe Lines and Tanks — TP-18A |
| **T-3.** | **General** |
| T-3A. | Corrosion Inhibitors — TP-9 |
| T-3B. | Identification of Corrosion Products — TP-11 |
| T-3C. | Annual Losses due to Corrosion — TP-13 |
| T-3D. | Instruments for Measuring Corrosion — TP-14 |
| T-3E. | Transportation — TP-15 |
| **T-4.** | **Utilities** |
| T-4A. | Effects of Electrical Grounding on Corrosion — TP-12 |
| T-4B. | Corrosion of Cable Sheaths — TP-16 |
| | T-4B-1. Lead and Other Metallic Sheaths — TP-16B |
| | T-4B-2 Cathodic Protection — TP-16C |
| | T-4B-3. Tests and Surveys — TP-16D |
| | T-4B-4. Protection of Pipe Type Cables — TP-16E |
| | T-4B-5. Non Metallic Sheaths and Coatings — TP-16F |
| T-4C. | Stray Railway Current Electrolysis — TP-16A |
| T-4D. | Corrosion by Deicing Salts — TP-19 |
| T-4E. | Analysis of Domestic Waters — TP-8 |
| **T-5.** | **Corrosion Problems in the Process Industries** |
| T-5A. | Chemical Manufacturing Industry — TP-5 |
| | T-5A-1. Sulfuric Acid — TP-5A |
| | T-5A-2. Stress Corrosion Cracking in Alkaline Solutions — TP-5C |
| | T-5A-3. Acetic Acid — TP-5D |
| | T-5A-4. Chlorine — TP-5F |
| | T-5A-5. Nitric Acid — TP-5G |
| T-5B. | High Temperature Corrosion |
| T-5C. | Corrosion by Cooling Waters |
| | T-5C-1. South Central Region — TP-8A |
| **T-6.** | **Protective Coatings** — TP-6 |
| T-6A. | Organic Coatings and Linings for Resistance to Chemical Corrosion — TP-6A |
| T-6B. | Protective Coatings for Resistance so Atmospheric Corrosion — TP-6B |
| T-6C | Protective Coatings for Resistance to Marine Corrosion — TP-6C |
| | T-6C-1 Pacific Coast Region |
| T-6E. | Protective Coatings in Petroleum Production — TP-6E |
| T-6G. | Surface Preparation for Organic Coatings — TP-6G |
| T-6H. | Glass Linings and Vitreous Enamels — TP-6H |
| T-6K. | Corrosion Resistant Construction with Masonry and Allied Materials — TP-6K |
| T-6L. | Asphalt Type Pipe Coatings |
| | T-6L-1. Pacific Coast Region |
| T-6M. | Field Coating Inspection |
| | T-6M-1. Pacific Coast Region — TP-6 Pacific Coast Div. |

its former entity in its new location. The only significant difference will be the new designations placing them in a pipe line group.

New Committees were formed as follows:

T-1 Oil and Gas Production is the same as old TP-1.

T-2 Pipe Line Corrosion is a combination of old committees whose primary interest is in corrosion of oil and gas pipe lines.

T-3 General is a combination of committees interested in problems of general nature.

T-4 Utilities is composed of committees concerned with corrosion problems of the utility industries.

T-5 Process Industries is concerned with problems in the chemical process industries.

T-6 Coatings is the same as old TP-6.

The increasing demand for regional committees is encouraged by the new rules because much can be accomplished at a local level. Regional committees are reorganized on a slightly different basis than under the old system. Any region may form a committee to work on any project. When two or more regional committees are working on the same subject, the activities will be coordinated. The method of establishing new committees is described fully in the procedures manual.

It is admitted that both the reorganization plan and the procedures manual are a compromise among varying ideas and may not represent the ultimate solution. Changes can and will be made in both as the occasion arises. NACE is a live and active organization. The technical committees are a vital part of NACE and can contribute much to the advancement of corrosion science. It is believed the reorganization and use of the new procedures manual will stimulate and aid committee activity.


## NACE Practice on Reprinting Technical Material

**Requests for prices on reprinting material appearing in CORROSION should be addressed to National Association of Corrosion Engineers, 1061 M & M Building, Houston 2, Texas. Prices usually cannot be given until after articles have appeared in CORROSION although requests for prices may be submitted at any time. Type from which technical articles are printed is kept standing for 90 days after date of issue, and reprints ordered during that interval will be from standing type. For reprints ordered after expiration of this period, write for details. Single copies of reprints of material from CORROSION are listed in advertisements appearing in many issues. Usually single copies may be obtained only in the form of tear sheets, or whole copies of the issue in which the article appears.**

**Permission to reprint articles usually is given to responsible firms and individuals who wish to have the work done themselves. NACE requires, however, that proper credit be given CORROSION at an appropriate place on all reprint material. The association also requests that reprint style closely conform to that approved by its board to be in keeping with the aims and objectives of the association and that copies of reprints made under this authority are supplied NACE for recording purposes.**

Progress Report

# Corrosive Effects of Deicing Salts *

## *TP-19—Corrosion by Deicing Salts**

**Abstract**

Deicing salt used in cities in the Northern part of the United States is estimated to cause an added $100,000,000 annual loss to automobiles and buried pipes and cables. Tests are related showing the effect of deicing salts on steel exposed to various concentrations of salts and the effect of inhibitors on reducing the corrosive effect of the salt. Various suggestions concerning the recommended mitigation practices for automobiles and underground power and communications cable and equipment are given. The lack of quantitative data on deicing salt corrosion losses and the need for additional research are emphasized.

MANY DIFFERENT materials are used and have been used for road, street and railway deicing. The use of chloride salts on snow or ice-covered roads is one of the principal means employed by municipalities, states and other public and private agencies to clear pavements for safe movement of vehicles and pedestrians.

The choice of chloride salts for this purpose stems from their low cost and their property of depressing the freezing point of water in relatively low concentrations.

The total amount of sodium chloride used for highways, railroads and other dust and ice control in the nation has increased from 412,000 tons in 1949 to 785,000 tons in 1951.[1] More than 97 percent of the salt thus used was rock salt, a mineral form of sodium chloride.

Calcium chloride is second to rock salt in deicing usage. Approximately 80,000 tons of calcium chloride is used annually.

In an article discussing methods of snow removal[2] W. S. Foster lists 34 cities where sodium chloride is used for deicing streets, either alone or in conjunction with abrasives such as cinders or sand. Among the larger cities mentioned are New York, N. Y., Detroit, Mich., Baltimore, Md., Buffalo, N. Y., Cincinnati, Ohio, Kansas City, Mo., Indianapolis, Ind., Albany, N. Y., Columbus, Ohio, Rochester, N. Y., Akron, Ohio, Toledo, Ohio, Hartford, Conn., Grand Rapids, Mich., Rome, N. Y., and Flint, Mich. Rock salt also has been used for deicing street railway switches in several of the larger cities including Chicago,[3] Detroit,[4] and Pittsburgh.[5] Geographically, the areas using deicing salts are north of a line drawn from the coastal border of Oregon and California through the Texas panhandle to the coastal border of Virginia and North Carolina.

That snow and ice removal may be a problem is indicated by the large snow falls in Northern cities. Buffalo, for instance, has an average snow fall of 74.1 inches per year and has recorded a high of 126.4 inches.[2] Albany, N. Y. has an annual fall of 50.0 inches and Rochester, N. Y. 78.7 inches.[6] These cities, as stated before, are among those using deicing salts. Sizeable amounts of deicing salts are being used, as much as 3500 to 30,000 tons a year, depending on the size of the city. On a per capita basis, the amount may vary from 7 to 70 lb. per year.

The degree to which brines resulting from the use of deicing salts contribute to the corrosion of vehicles has been a moot question, as evidenced by conflicting reports.[7] There also has been difference of opinion with respect to the influence of the salts on corrosion of subsurface metallic structures. The following report will discuss corrosion of above and below ground structures as influenced by deicing salts.

Corrosion of 38,000,000 automotive vehicles, attributed to all causes, has been estimated to cost $1,100,000,000 annually.[8] American industry is paying in the order of $1 billion annually for corrosion on its 1.7 million miles of buried pipes and cables.[9] If, for the purpose of discussion, the portion of corrosion caused by deicing salts is assumed tentatively at 5 percent of all corrosion, it is seen that the annual loss attributable to deicing salts is approximately $100,000,000. Reduction of a corrosion loss of this magnitude thus presents a challenge to corrosion engineers and municipalities.

### Corrosion of Above Ground Structures

The type of atmosphere will determine to a great extent the basic corrosion rate of steel. Urban atmospheres are usually between industrial and rural in corrosivity. The relative merits of identical steels in various urban atmospheres therefore may not be the same. Steels exposed to a marine atmosphere do not, as a rule, develop rust films as protective as they do in an industrial atmosphere. Presumably the basic sulfur compounds that confer protection in industrial atmospheres are made more permeable by the development of soluble chlorides in marine atmospheres.[10] Viewed in this light, the use of deicing salts may result in greater corrosion than the basic rate but hardly can be expected to reduce the rate of atmospheric corrosion.

★Prepared by the committee, formed by the National Association of Corrosion Engineers to investigate corrosion by deicing salts on metallic equipment above and below ground and to study and recommend mitigative measures.

*F. E. Kulman, Consolidated Edison Co. of New York, N. Y., chairman.

Preliminary tests on test panels mounted on automobiles indicated that the corrosion rates of mild steel in two Michigan cities in the absence of sodium chloride were 14.6 and 16.6 mdd (milligrams per square decimeter per day). These losses correspond to penetration rates of .00267 and .00304-inch per year. Corrosion rates in two cities in Michigan and New York where moderate amounts of rock salt were used were 27.9 and 36.4 mdd.[11] From these limited data it would appear that the effect of sodium chloride would be to approximately double the basic corrosion rate.[12] These data are not conclusive in view of the relatively small numbers of panels tested, differences in weather between cities from month to month and lack of control of the salt spreading practices. The severity of the weather of a given season and the local practice with respect to salting would be expected to affect the magnitude of both the basic corrosion rate without salts and the over-all rate with salts. Data abstracted from several field test reports by LaQue[13] show that the use of salt caused a 35 to 40 percent increase in corrosion rate.

Most of the interest reported in the literature has been centered on the corrosion of automobile bodies, particularly the underside of fenders and the vulnerable fender-body joint. According to LaQue and Hergenroether,[14] the most adverse factor in the corrosion of automobile underbodies is that they have limited opportunity to dry out. This observation extends also to insides of doors or other relatively confined spaces in which the moisture in warm air, drawn in during the day, will condense at night. This condensate, plus rain that may leak in around window openings, must obviously be given an opportunity to drain immediately if corrosion is to be avoided. Quick and thorough drying of hidden surfaces is important not only through its direct effect in removing a corrosion influence, but indirectly as it increases the protective value of the rust films that form on steel.

### Remedial Measures for Above Ground Corrosion

It has been suggested that car users can help themselves most by keeping or parking their cars where they will have a chance to dry quickly and by washing them often enough to get rid of accretions of salts and mud which may accelerate corrosion.[14]

Several automobile manufacturers are eliminating the body-fender joint on their newer designs with the expectation that corrosion at the fender-body joint will be reduced. Similarly, moisture pockets in other structures can be eliminated by improved design.

Car manufacturers have been advised that "to the extent that it may be practical, the underbodies of cars should be designed with quick drying in mind. This could conceivably include the use of air channels and guiding vanes to insure that ample supply of drying air, preferably that taken from under the hood where it will be warmed, is channeled to surfaces that might not be subjected to the required drying effect without the benefit of such controlled, underbody ventilation."[14]

Another design approach is to make corrodible areas accessible for repair of coating. This would apply to bridges, viaducts, and other steel structures in addition to automobiles. The improved performance resulting from better surface preparation and use of corrosion resistant steels also deserves consideration.

Treatment of the salts with corrosion inhibitors is being tried in various cities. Sodium dichromate, added to sodium chloride in the ratio of one pound of inhibitor per 100 pounds of salt, was tested in Akron in the winter of 1947-1948. Observations were made on 116 automobiles and these cars were compared with similar cars operating in areas where no inhibitors were used. It was concluded from these studies that chromates in sufficient concentration would arrest the corrosion at the body and fender joints that otherwise would continue throughout the summer every time the car became wet.[7] Polyphosphate type inhibitors were also found to be effective in Akron.

On the basis of field tests conducted in Rochester, N. Y. during the 1948-1949 winter it was reported that the corrosive action was reduced by adding a polyphosphate type inhibitor to the rock salt. However, because of variables, many of them beyond human control, wide variations in individual weight losses of the steel test panels were encountered. Additional testing was suggested in order to arrive at more dependable results.[15]

Field tests conducted in two nearby Michigan cities in the early months of 1949 showed that the use of a polyphosphate type inhibitor with rock salt reduced the over-all corrosion rate of steel by 22 to 26 percent.[12]

Other data, based on inspections of several thousand automobiles (1948, 1949 and 1950 models) in service in various cities in 1951, indicated that the rate of failure at the fender welt and other areas was at least as high in Rochester and Akron where inhibitors were used as in other cities where salt was used without inhibitors.[16]

The application of better organic coatings has been suggested to mitigate deicing salt corrosion. For trim on automobiles, better care of the plate in respect to cleaning, waxing, oiling or lacquering has been recommended for prolonging life.[17]

### Corrosion of Underground Structures

Deicing salt brines apparently seep underground through breaks in street pavements, manhole and vault openings, gas valve boxes and other access openings into the underground cable and piping systems. The salt content of manhole waters and earth electrolytes has been found to be increased by deicing salt additions.[18] Consequently when deicing salts are used, increased corrosion may be expected to result on underground structures from chemical action, stray and galvanic currents as discussed below.

In cities where street cars still operate, the lead sheaths of power and telephone cables are subjected to increased corrosion, in the presence of stray currents, at locations where the cable sheaths are cathodic and where sodium chloride is used for deicing of street railway switches. The corrosion is believed to result from the electrolysis of the salt and the

accumulation of sodium hydroxide at the lead sheath. Because lead is amphoteric, it will tend to be dissolved by the hydroxide. The final corrosion product usually consists of lead monoxide and lead carbonates. In Detroit, it has been reported that 53 telephone cables have failed because of cathodic corrosion caused by sodium chloride used for deicing.[4] Cathodic corrosion of telephone cables also has been reported in Pittsburgh.[5] There were 27 cable failures caused by cathodic corrosion on the Chicago telephone system in 1951 and four locations at which six or more cable failures have occurred in the last 10 years.[19]

Electrolytic corrosion of anodic portions of lead sheaths appears to be accelerated by salt brines lowering the resistivity of the earth, resulting in larger current discharges. One of the primary factors in underground cable corrosion has been reported to be low resistance electrolytes in cable ducts.[20]

Corrosion of underground cable sheaths also has been reported to occur in the absence of stray currents. In duct lay cable much corrosion results from unfavorable duct and soil conditions.[20] In manholes, where dissimilar metals are used, the presence of salts seems to lower the resistivity of the manhole waters and to cause an accompanying increase in galvanic current between the dissimilar metals, such as the lead sheath and copper bond wires and between cable sleeves and brass or bronze splice fittings.[3] Deicing salts may also accelerate the corrosion of steel tanks of transformers and network protectors at the junction with copper grounding studs, brass valves and other operating fixtures.[18]

Tests made on steel panels installed in underground manholes in New York City showed corrosion rates of 32.9 mdd in non-salt areas and 38.7 mdd in salt (NaCl) areas. The corresponding penetration rates were .0060 and .0071-inch per year. These results were obtained during a mild winter when the 17-inch snow fall was approximately half the normal amount. Correlation was found between corrosion rate and sodium chloride concentration of the manhole water.[21]

### Remedial Measures For Underground Corrosion

Flushing of the underground cable ducts with fresh water has been found to reduce the salt concentration of duct waters in Detroit,[4] Pittsburgh,[5] and New York.[20] The importance of maintaining the continuity of communication cable circuits is illustrated by the estimate that the cost of flushing 80 duct sections, as was done in one year in Pittsburgh, was considered justified if failure of one major cable was prevented.[5]

In addition to flushing the ducts, a coating of corrosion preventive grease has been used on new cables and on cable repairs to retard future corrosion.[19,20] This coating has been found to be effective in preventing corrosion of lead sheathed cables, but at least one company has discontinued its use due to the hazard to polyethylene sheathed cable which may be present or may be installed later in the duct system. The present policy of one company is to dig up and repair the cable if the corrosion appears to be localized, trusting to the conduit repairs and its consequent removal of existing salt which contacted the sheath to retard future corrosion. If the corrosion is extensive, the cable is replaced with a nonmetallic sheathed cable or with a lead sheathed cable protected by a plastic jacket approximately 0.1-inch thick. Submersible transformers and network protectors are painted with coal tar base paints. Keeping the manholes clean of accretions of salt and mud has been found to be of help in reducing corrosion.[18]

There does not appear to be any reference to field data pertaining to the effects of corrosion inhibitors on the rate of cathodic corrosion of lead cables nor does there appear evidence to indicate that inhibitors will be effective in preventing anodic or galvanic corrosion of lead and steel.

### Laboratory Tests

Laboratory alternate immersion tests have been devised to evaluate the relative corrosion rates of brines on steel surfaces and the reductions in corrosion rates expected to result from the use of inhibitors. Two test procedures have been described in some detail.

In the Temmerman and Sterlin tests,[15] specimens of 22-gauge mild steel, 2¾ inches by 5⅞ inches, were drilled with a hole at one end, stamped with a code number, degreased and weighed. The panels were immersed in the brine of fixed concentration for three hours, withdrawn and air-dried for two hours, reimmersed in the same brine for 17 hours overnight, withdrawn and air-dried for two hours. This cycle was repeated five times or for five days. After cleaning, the loss of weight was determined by re-weighing. Tests were made in various concentrations of rock salt in distilled water, with and without additions of the polyphosphate type inhibitors.

Results of tests using this procedure indicated that in the absence of inhibitors, the corrosion loss of steel increased with increasing concentrations of rock salt brine up to a maximum at 4 percent brine. At higher rock salt concentrations, the corrosion rate decreased from the maximum. The effect of adding the inhibitor in concentrations of 0.5-lb and 1.0-lb per 100 lb of rock salt was to increase the corrosion in dilute solutions (one percent rock salt) and to reduce the corrosion in concentrated solutions (5 percent rock salt). An inhibitor concentration of 2.0-lb per 100 lb of rock salt resulted in reduced corrosion in all concentrations.

In the procedure developed by Roland and Ralston,[11] variations in the above described procedure were introduced. Panels of steel, 2 inches by 3 inches, were immersed in agitated rock salt solution for one hour in the morning, removed from the solution for five hours, returned to the solution for one hour and then removed from the solution for seventeen hours. The test was continued for four days.

Results, using this procedure, indicated that corrosion of steel increased with increasing concentrations of rock salt up to a maximum at approximately 8 percent concentration. Beyond this point, the corrosion rate decreased as the concentration was further increased. Polyphosphate type inhibitors in con-

centrations of 0.5 to 1.0-lb per 100 lb of rock salt appeared to be ineffective in one percent rock salt solution but reduced corrosion in brines having concentrations of five percent rock salt and higher. Inhibitor concentrations of 2 percent, or 2.0-lb per 100 lb rock salt, were much more effective in brines below 5 percent rock salt.

## Summary

The foregoing report has been concerned primarily with outlining the complex problem of deicing salts corrosion. Deicing salts, as seen from a review of published information, increase the corrosion and thereby cause economic loss of metallic equipment both above and below the ground surface. This does not imply that deicing salts are the sole or primary cause of corrosion above ground or underground.

Relatively little quantitative data have been published to indicate the corrosion rates attributable to the use of deicing salts. These vary with the severity of the winter and the local practices with respect to salting. The field tests that have been reported serve to indicate that significant factors other than deicing salts are also responsible for a portion of the corrosion being experienced. The need for further investigation of these factors is apparent.

Remedial measures for mitigating deicing salts corrosion above ground are pointed out. These include washing the salts and mud accretions from the underside of automobiles, keeping the car in a dry environment, maintenance of protective coatings, treatment of the salts with inhibitors and suggestions for design changes.

Mitigative measures for subsurface corrosion of lead sheathed cables are indicated, including flushings of the cable ducts and protective coatings.

A brief description of laboratory tests to determine the corrosive effect of deicing salts is given.

## Future Work

Additional field testing is required to determine more accurately the increased corrosion rates of steel and other metals caused by the growing use of deicing salts in various cities.

Further field testing is necessary to determine what amounts of corrosion inhibitors or mixtures of such inhibitors are required to effectively reduce corrosion by deicing salt brines.

Non-corrosive chemical substitutes for deicing salts should be investigated and tested in the laboratory and in the field.

Further improvement of protective coatings for above ground and underground applications is indicated.

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# Corrosion by Acids at High Temperatures*

By R. F. MILLER, R. S. TRESEDER and A. WACHTER

IN RECENT YEARS interest has been increasing in chemical processes involving reactions of liquids at temperatures above their normal boiling points and at high pressure. At an early stage in development of such processes it is necessary to know the corrosive characteristics of the system. This information is needed

1) to assist in early economic evaluation of the process,
2) to allow selection of suitable materials for pilot plant equipment, and
3) to evaluate process variations that might lead to less costly plant construction.

Corrosion data in the published literature are rarely applicable since they generally are for temperatures that do not exceed the normal boiling point. Extrapolation of such data to higher temperatures would be unwise.

Laboratory corrosion testing at high pressure and temperature conditions tends to be a laborious and costly operation. Special pressure vessels are required with openings large enough to insert specimens. Selection of a material of construction for the pressure vessel is a problem because the vessel must be almost completely resistant to attack to avoid complications arising from contamination of the liquid with corrosion product. Pressure vessels designed for work on one problem may be unsuitable for the next problem.

Presented here is a simple test method which has proved to be convenient, adaptable and generally useful for corrosion tests at elevated temperatures and pressures. In addition, laboratory corrosion data obtained by this method are presented for a number of common corrosive liquids.

## Test Method

The test method consists of placing a small test strip in a heavy-walled glass tube containing a small volume of the corrosive liquid. Air in the tube may be replaced by another gas or evacuated. The tube is flame-sealed and placed in a vertical position in a constant temperature oven for the test period desired. The pressure in the tube reaches the equilibrium value for the test temperature. Test details are discussed in the following paragraphs.

*Specimens*

The size of specimen usually employed is 0.125 x 0.25 x 2.0 inches. For a single specimen, totally immersed, no specimen support is needed. When it is desired to expose a specimen to the vapor phase or to both vapor and liquid phase, simple glass supports

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## Abstract

A test method is described for obtaining corrosion data with acids and other corrosives at temperatures above their normal boiling points. The method, which has features of simplicity and general usefulness, involves use of a flame-sealed heavy-wall glass tube as container for the metal specimen and corrosive fluid. The atmosphere over the fluid can be controlled and, by evacuating the tube before sealing, can be made to consist only of the equilibrium vapor at test temperature. It is estimated that the tubes withstand gas pressures up to about 1000 psig which corresponds to a test temperature of 285 degrees C for water. Appropriate test safeguards are described.

Corrosion data obtained by this method are presented for various alloys exposed to sulfuric acid, phosphoric acid, nitric acid, formic acid, boric acid and phenol at different temperatures and concentrations. An interesting general observation from these corrosion data is the relatively good corrosion resistance of copper in sulfuric, phosphoric, boric and formic acid solutions.

can be used. The usual weight loss and pit depth measurements are made. Small stressed specimens of the U-bend type can be used if stress corrosion effects are to be evaluated. Constant-load beam specimens have also been employed (see Figure 1).

*Tubes*

The glass tubes used have outside diameters of ⅝-inch to 1-inch (17 to 25 mm) with wall thickness of ⅛ to 1/16-inch (2 to 3 mm). Pyrex combustion tubes, which have these dimensions and which come sealed at one end are available in 12-inch (300 mm) lengths, a size convenient for most tests. Experience has indicated that these tubes, if properly sealed, will withstand pressures of the order of 500 psig and can be used with moderate success at pressures up to 1000 psig, which corresponds to a test temperature of 285 degrees C for water.

*Corrosive*

The volume of corrosive liquid commonly used in these tests is 10 to 15 ml. Larger volumes should be employed when the corrosive constituent is present in small concentrations.

The vapor space in the tube (*ca* ⅔ of total volume) may be evacuated if desired, or may be filled with air, nitrogen, carbon dioxide, hydrogen sulfide, hydrogen chloride or other gas. Even low flashpoint liquids may be tested, provided the tubes are cooled in ice or solid carbon dioxide just prior to flame sealing.

*Tube Sealing Procedure*

A rubber stopper with glass tubing through it, inserted into the end of the combustion tube serves as a handle for sealing the tube. If an obnoxious material such as hydrogen sulfide is in the tube a length of rubber tubing may be extended from the glass tube to a fume hood. This rubber tube also may connect to a vacuum pump if it is desired to evacuate the tube before sealing. A hand torch (gas, oxygen) or crossfires are used for sealing. With tubes 12 inches long the tubes are sealed about 9 inches from the lower end. In sealing, the tubing is heated and the wall section thickened as the glass is pulled to a capillary which is fused at the end (see Figure 2). If the tube is to be evacuated, it is necessary to seal it in two steps:

1) the tube is flame drawn to a heavy wall small diameter cross section and

2) evacuated and sealed in this reduced section.

*Safety Precautions*

For safety during the test the sealed glass tube should be inside a metal container to stop the fragments in case of tube failure. Such containers may be constructed easily from cap closed sections of threaded 1¼-inch pipe with a few small holes drilled in the cap to serve as vents. The shielded glass tube is stored vertically in a constant temperature oven during the test. One type of oven designed specifically for this test is shown in Figure 3. When a combustible liquid is being tested, the upper space

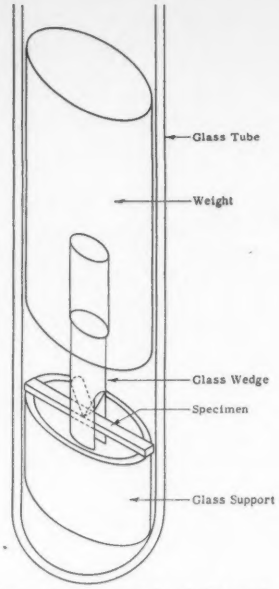


Figure 1—Constant-Load Stressed Beam Test.

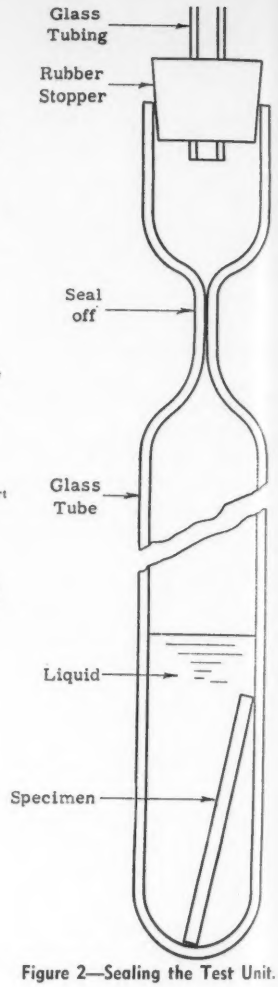


Figure 2—Sealing the Test Unit.

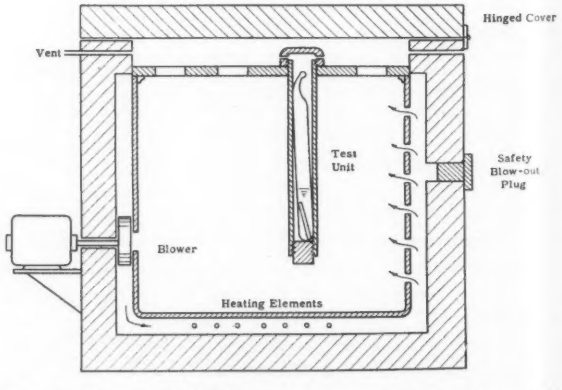


Figure 3—Oven for High Temperature Corrosion Tests. (Capacity 16 sealed glass tubes.)

in this oven is continuously swept out with an inert gas in order to reduce the hazard of fire or explosion in the event a tube should burst.

Following exposure the tubes are cooled in their metal containers. The tip of the tube is slid out of the metal container and broken off with a pair of

pliers. During this operation the open end of the protective tube should always be pointed away from the person opening it and from others in the laboratory. The wearing of a protective face shield and gloves is advisable. Breaking the glass tip relieves pressure in the tube which then may be broken in two by a hot wire or any other convenient means.

Despite the inherent hazards involved in conducting tests of this type, following the foregoing safety precautions has allowed several thousand tests to be made in Shell Development Company laboratories without a single injury to personnel.

*Advantages and Limitations*

The principal advantage of the test is its simplicity which permits making a large number of tests in a short time. It is possible, for example, for a single laboratory assistant to make 20 tests a day, including all operations necessary for setting up the tests and taking them down. Thus a wide range of variables such as corrosive concentration, temperature, alloy composition and inhibitor evaluations may be studied almost simultaneously. Use of an all-glass system eliminates concern about effects of metal ion contamination of the corrosive by the apparatus.

One of the limitations of the method is the absence of mechanical agitation, which in many systems would lead to low corrosion rate values. This objection may not be serious if results are being considered on a relative basis. Another limitation is the small amount of liquid that can be used; this could lead to depletion of the corrosive during test if the corrosive were present at a low concentration. If the corrosive constituent is gaseous, pressure control and therefore concentration, may be quite difficult. The method, of course, is not applicable to strongly alkaline solutions or fluoride solutions which would attack glass.

Experience has shown that the method has considerable value as a screening test for making a quick survey to indicate what alloys may be useful or what process conditions are most promising from a corrosion viewpoint. The most promising solution to the problem can be examined then in greater detail using more complex corrosion test methods capable of giving a complete evaluation, e.g., tendency for localized attack, stress corrosion, etc.

In the following portion of the paper are presented data obtained by this method for a number of common corrosive systems at elevated temperatures.

## Corrosion Data

*Dilute Sulfuric Acid*

The relative corrosion resistance of a number of alloys in 5 percent sulfuric acid at 220 degrees C is presented in Table 1. In addition some data for 25 percent sulfuric acid at 220 and 250 degrees are presented. Only gold, platinum, tantalum and silver were resistant under the test conditions. Copper showed moderate resistance to attack with the 5 percent acid but an increase of concentration to 25 percent caused a marked increase in the corrosion rate. Copper showed markedly better corrosion resistance than other metals and alloys, such as lead or Monel, which normally would be considered better materials for handling dilute sulfuric acid at low temperatures. It should be pointed out that in all cases the acid contained a small amount of ethyl alcohol and tests were made in the absence of air. Subsequent tests in pilot scale process equipment indicated that the corrosion data obtained by the above tests were substantially correct; although higher corrosion rates were obtained with copper, presumably a consequence of the effect of flow velocity.

Corrosion data for copper in 5 and 25 percent sulfuric acid at 100 to 275 degrees C are presented in Figure 4. With 5 percent acid the corrosion rate was quite low (<5 mils/yr) at or below 200 degrees C, but increased rapidly above this temperature. For 25 percent acid high rates were observed above 150 degrees C.

*Phosphoric Acid*

Corrosion data for a number of metals in 85 percent phosphoric acid at 250 degree C are presented in Table 2. Silver and tantalum were the most resistant materials tested (7 and 20 mils/yr). Moderate attack of copper (58 mils/yr) was observed. As was noted with sulfuric acid, copper was appreciably more resistant to attack in phosphoric acid at high temperatures than alloys such as Type 316 stainless steel, which normally would be the more resistant material at ordinary temperatures.

**TABLE 1—Corrosion by Dilute Sulfuric Acid Containing Ethyl Alcohol**

Conditions:
- 0.5-inch diam. x 8-inch long Pyrex tube.
- 3 to 7 ml of 5 or 25 percent aqueous sulfuric acid containing 1 percent ethyl alcohol.
- Single specimen, 0.1 x 0.25 x 2.0-inch ground surface, totally immersed.
- Tube evacuated at room temperature before sealing. No agitation. Duration, 1 day.

| ALLOY | CORROSION RATE, MILS/YR. | | |
|---|---|---|---|
| | 220° C | | 250° C |
| | 5% $H_2SO_4$ | 25% $H_2SO_4$ | 25% $H_2SO_4$ |
| Gold | <0.5 | .... | 2. |
| Platinum | <0.5 | <0.5 | 0.5 |
| Tantalum | .... | .... | <0.5 |
| Silver | 2. | 7. | 20. |
| Copper | 10. | 700. | 1500. |
| Everdur 1010 | 10. | .... | .... |
| Monel | 530. | .... | .... |
| Nickel | 530. | .... | .... |
| Lead | 220. | .... | .... |
| Type 317 Stainless Steel | 390. | .... | .... |
| Worthite | 260. | .... | .... |

**TABLE 2—Corrosion by Phosphoric Acid at 250° C**

Conditions:
- 0.5-inch diam. x 8-inch long sealed Pyrex tubes.
- 10 ml. of c.p. phosphoric acid solution.
- Single test specimen 0.1 x 0.25 x 2.0-inch ground surface totally immersed per tube.
- Tube evacuated at room temperature before sealing. No agitation. 250° C. Duration, 1 day.

| ALLOY | CORROSION RATE, MILS/YR. |
|---|---|
| | 85% $H_3PO_4$ |
| Silver | 7. |
| Tantalum | 20. |
| Copper | 58. |
| Nickel | 1200. |
| Monel | 1100. |
| Lead | 5600. |
| Type 317 Stainless Steel | 4300. |

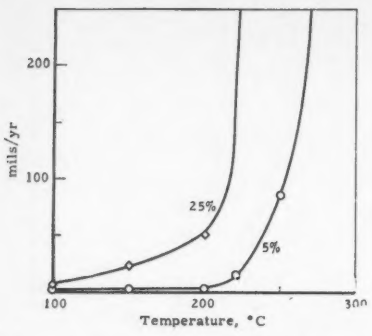


Figure 4—Corrosion of Copper by Sulfuric Acid. Conditions as in Table 1. Extension of curves above plotted points determined by data above upper range of graph.

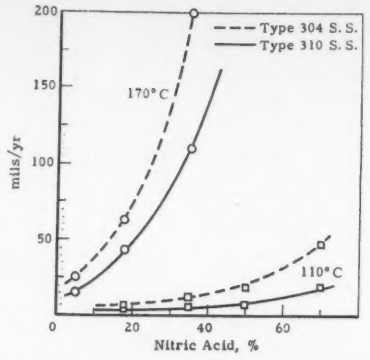


Figure 5—Nitric Acid Corrosion of Type 304 and Type 310 stainless steel. Corrosion of Type 304 and Type 310 stainless steel in nitric acid at temperatures and concentrations indicated. Tests as described in Table 3. Extension of curves above plotted points determined by data above upper range of graph.

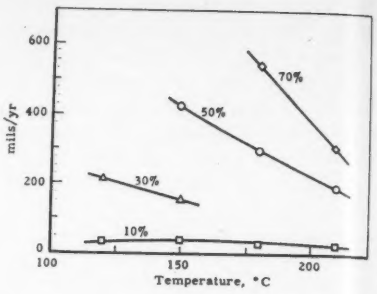


Figure 6—Corrosion of Steel by Boric Acid. Conditions: Sealed glass tubes containing 10 grams of aqueous boric acid. One 0.1 x 0.25 x 2.0 in. ground steel test specimen per tube. Tubes evacuated, stagnant. Duration, one day.

**TABLE 3—Corrosion of Various Alloys by Nitric Acid Containing Traces of Organic Acids**

Conditions:
0.6-inch diameter x 8-inch long sealed Pyrex tube.
20 ml of 18%w nitric acid containing 0.2% formic acid. Tests at 150° C and 200° C also contain 6% of terephthalic acid.
Single specimen 0.1 x 0.25 x 2.0-inch ground surface totally immersed.
Air atmosphere. Stagnant. Duration, 1 day.

| ALLOY | CORROSION RATE, MILS/YR.[a] 150° C | 175° C | 200° C |
|---|---|---|---|
| Type 304 Stainless Steel | 25-41 | 64 | 500 |
| Type 310 Stainless Steel | 16-25 | 37 | 330 |
| Type 317 Stainless Steel | 19 | 56 | 320 |
| Type 430 Stainless Steel | .... | 200 | .... |
| Type 446 Stainless Steel | 30 | 83 | 290 |
| Carpenter 20 | .... | 43 | .... |
| Worthite | .... | 100 | .... |
| Ilium R | 9 | 36 | 290 |
| Platinum | .... | <1 | <1 |
| Gold | .... | <1 | <1 |
| Tantalum | 1 | <1 | <1 |
| Titanium | 4 | 4 | 6 |
| Inconel | .... | 4300[b] | .... |
| Duriron | .... | 110 | 90 |

[a] From weight loss and exposure time. No localized attack observed.
[b] Specimen penetrated.

**TABLE 4—Corrosion by Nitric Acid Containing Traces of Organic Acids at 200° C**

Conditions:
As in Table 3.
Nitric acid of indicated concentration containing 0.2% formic and 6% terephthalic acids.
One day exposure at 200° C. No agitation.

| ALLOY | Nitric Acid % w | Corrosion Rate, Mils/Yr.[a] |
|---|---|---|
| Tantalum | 18 | <1. |
| Tantalum | 35 | <1. |
| Tantalum | 50 | <1. |
| Tantalum | 70 | <1. |
| Titanium | 18 | 6. |
| Titanium | 35 | 4. |
| Titanium | 50 | 4. |
| Titanium | 70 | 4. |
| Duriron[b] | 18 | 86. |
| Duriron[b] | 35 | 5. |
| Duriron[b] | 50 | <1. |
| Duriron[b] | 70 | 7. |

[a] From weight loss and exposure time. No localized attack observed.
[b] No terephthalic acid present.

In subsequent tests in pilot plant equipment and with turbulent acid somewhat higher rates were observed with copper. However, copper specimens protected from rapid acid flow were attacked at the lower rates observed in the tube tests. Silver also was attacked at a higher rate under turbulent flow conditions.

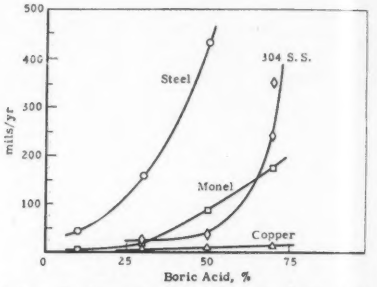


Figure 7—Corrosion of Alloys by Boric Acid at 150 degrees C. Conditions: As in Figure 6.

*Nitric Acid*

Stainless steels usually are resistant to attack by nitric acid solutions at temperatures below the normal boiling point. Sealed tube tests have shown that the various stainless steel alloys are corroded severely at elevated temperatures.

In initial one-day tests with c.p. nitric acid, quite low corrosion rates were obtained with austenitic stainless steels. However, prolonged exposure to nitric acid resulted in appreciable corrosion. When small amounts of formic acid and terephthalic acid (both present in the particular reaction under investigation) were added to nitric acid, appreciable corrosion (20 to 500 mils/yr) of stainless steel was observed in short term (<1 day) tests.

Corrosion data from a series of tests with nitric acid of various concentrations (5 to 70 percent with formic and terephthalic acids present) at 110 to 200 degrees C are presented in Tables 3 and 4, and Figure 5.

Of the metals and alloys tested only platinum, gold, tantalum and titanium appeared resistant to attack. Type 304 stainless steel was attacked markedly by nitric acid solutions (above 18 percent concentration) at temperatures above the normal boiling point. Other stainless steels tested showed no significant differences in corrosion resistance. These

observations regarding poor corrosion resistance of stainless steels in nitric acid at elevated temperatures are in general agreement with the data reported by Fontana.[1] The observation that Type 310 stainless steel was not appreciably more resistant to attack than Type 304 was not in agreement with information presented by Lee.[2] Duriron appeared resistant to concentrated nitric acid at 200 degrees C but was attacked by dilute solutions at 175 degrees C.

*Boric Acid*

Data relating to the corrosion of steel by boric acid solutions (10 to 70 percent) at 120 to 210 degrees C are presented in Figure 6. Moderate to severe corrosion of carbon steel was observed at concentrations greater than 10 percent boric acid. It should be noted that the corrosion rate decreased rapidly as the solution became saturated with iron (similar to experience with concentrated sulfuric acid at low temperatures). Thus, rates of attack would be less for iron-saturated boric acid, but severe attack might be expected on steel in fresh boric acid. The relative resistance of steel, copper, Monel and Type 304 stainless steel to boric acid (10 to 70 percent) at 150 degrees C is shown in Figure 7. Copper was quite resistant to all concentrations of boric acid tested. Monel and 18-8 stainless steel were resistant to dilute boric acid (30 percent or less), but the corrosion rate increased rapidly at higher concentrations. The corrosion rate of steel was moderately high (40 mils/yr) with 10 percent boric acid, but appreciably greater with more concentrated solutions.

*Formic Acid*

Corrosion data for various alloys in *ca* 5 percent formic acid at 170 degrees C are presented in Table 5. Formic acid was quite corrosive to nickel, most stainless steels and aluminum. Comparatively resistant were copper, silver and Type 446 stainless steel. The effect of temperature and acid concentration on corrosion of Type 316 stainless steel is given in Table 6. At 100 degrees C slight to moderate corrosion was observed; at 150 degrees C and higher, increased corrosion occurred with pronounced localized attack. The above data complement those presented by Teeple,[3] who showed that moderate attack of Type 304 stainless steel occurred in 2 percent formic acid solution at 150 degrees C.

With stainless steels high corrosion rates (>60 mils/yr) were obtained in short term tests with a sandblasted surface or an evacuated tube, whereas erratic rates (1 to 100 mils/yr) were obtained with a ground surface or an air atmosphere in the tube.

In sealed tube tests with 5 percent acetic acid at 170 degrees C, Type 316 stainless steel was only slightly attacked (5 mils/yr), while 2S aluminum again was attacked at a high rate.

**TABLE 5—Corrosion by Formic Acid**

Conditions:
1.0-inch diam. x 8.0-inch long Pyrex tube.
12 ml of 4.6 percent aqueous formic acid.
Single 0.1 x 0.25 x 2.0-inch specimen totally immersed. Ground surfaces except for stainless steels which were sandblasted and aluminum which had been prepared by rubbing with rubber eraser containing abrasive.
Tubes evacuated at room temperature before sealing. Test temperature 170° C. No agitation. Duration, 1 day.

| ALLOY | CORROSION RATE, MILS/YR. General | Max. Localized |
|---|---|---|
| Silver | 6. | .... |
| Hastelloy B | 9. | .... |
| Hastelloy C | 4. | .... |
| Copper | 8. | .... |
| Monel | 29[a], 42[a] | .... |
| Nickel | 92. | .... |
| Inconel | 130. | .... |
| Type 304 Stainless Steel | 140. | 760. |
| Type 310 Stainless Steel | 93. | .... |
| Type 316 Stainless Steel | 73. | 380. |
| Type 317 Stainless Steel | 63. | 490. |
| Type 410 Stainless Steel | 640. | .... |
| Type 430 Stainless Steel | 410. | .... |
| Type 446 Stainless Steel | 14, 38 | .... |
| Aluminum 2S | 400. | .... |
| Duriron | 290. | .... |
| Carbon Steel | 1200. | .... |

[a] Evidence of denickelification.

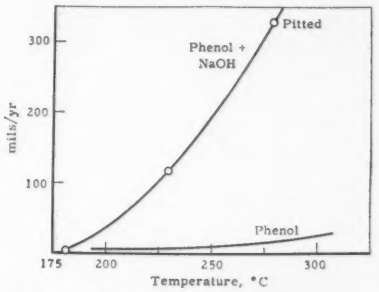


Figure 8—Corrosion of Steel by Phenol Containing Caustic Soda. Conditions: 1.0-inch diam. x 8.0-inch long Pyrex tube. 15 ml of phenol plus 0.7%w of 50% aqueous sodium hydroxide. Single carbon steel specimen 0.1 x 0.25 x 2.0-inch ground surface totally immersed. Nitrogen atmosphere. Duration, 1 day. No agitation. Data on phenol from Wachter and Stillman paper.[4]

**TABLE 6—Corrosion of Type 316 Stainless Steel by Formic Acid**
Conditions as in Table 5.

| Formic Acid, Percent w | CORROSION RATE, MILS/YR. Temperature °C | General | Max. Localized |
|---|---|---|---|
| 1 | 150 | 5. | .... |
| 1 | 170 | 8. | .... |
| 1 | 200 | 35. | .... |
| 4.6 | 100 | 23. | .... |
| 4.6 | 150 | 60. | 500 |
| 4.6 | 170 | 72. | 400 |
| 4.6 | 200 | 66. | .... |
| 24 | 100 | 41. | .... |
| 24 | 150 | 120. | 500 |
| 24 | 200 | 130. | 1000 |

**TABLE 7—Corrosion by Phenol Containing Hydrogen Chloride and Water**

Conditions:
1.0-inch diam. x 8-inch long Pyrex tube.
15 ml of phenol containing 2%w of dilute HCl solution (13%w HCl) with single 0.1 x 0.25 x 2.0-inch ground specimen per tube.
Nitrogen atmosphere, no agitation. Test temperature 192° C. Duration, 1 day.

| ALLOY | Corrosion Rate, Mils/Yr.[a] |
|---|---|
| Tantalum | <0.4 |
| Hastelloy B | 2. |
| Monel | 17. |
| Type 304 Stainless Steel | 37.[b] |
| Type 316 Stainless Steel | 23. |
| Titanium | 37.[b] |

[a] From weight loss, no localized attack observed.
[b] Corrosion rate may be low due to depletion of corrosive during test.

*Phenol*

Corrosion data obtained by this method for phenol at 150 to 350 degrees C, were reported previously by Wachter and Stillman.[4] They showed that anhydrous phenol was moderately corrosive to carbon steel at temperatures above 250 degrees C, but that presence of traces of water had an inhibiting effect. Subsequent tests have shown that the presence of a small amount of aqueous sodium hydroxide in the phenol has a strongly accelerating effect on corrosion of carbon steel at temperatures above 180 degrees C (Figure 8). The corrosion rates of copper, Monel and Type 304 stainless steel in this test at 288 degrees C were less than 3 mils per year. High corrosion rates for carbon steel in phenol have also been obtained with anhydrous mixtures of phenol and sodium hydroxide. The addition of sufficient water (*ca* 5 percent) had an inhibiting effect on the corrosion of steel. An explanation for the accelerating effect of sodium phenolate on corrosion of carbon steel in this system is not readily apparent.

Corrosion tests with phenol containing a small amount of water and hydrogen chloride at 192 degrees C are presented in Table 7. Of the materials tested only tantalum and Hastelloy B appeared resistant to attack. Monel, titanium, Type 304 and 316 stainless steel all were corroded at moderate rates.

### Corrosion Resistance of Copper

An interesting general observation from these corrosion data is the relatively good corrosion resistance of copper in sulfuric, phosphoric, boric, and formic acid solutions as compared to austenitic stainless steels, Monel and nickel. This is in contrast with the experience at lower temperatures with these acid solutions wherein the latter alloys are often preferred over copper.

### Acknowledgment

The authors acknowledge the cooperation of their colleagues in the Corrosion Department of Shell Development Company.

**TABLE 8—Nominal Composition of Alloys Employed in Corrosion Tests**

| ALLOY | Nominal Chemical Composition, Percent w |
|---|---|
| Carbon Steel | 0.1 Si, 0.3 C, 0.01 P; Fe |
| Aluminum 2S | 0.2 Cu max., 1.0 Fe+Si max.; Al |
| Copper | 99.9 Cu |
| Everdur 1010 | 0.09 Fe, 1.0 Mn, 3. Si; Cu |
| Nickel | 99 Ni |
| Monel | 1 Mn, 1.4 Fe, 30 Cu, 67 Ni |
| Inconel | 6.5 Fe, 13 Cr, 79.5 Ni |
| Hastelloy B | 6 Fe, 32 Mo; Ni |
| Hastelloy C | 5 W, 6 Fe, 17 Cr, 19 Mo; Ni |
| Illium R | 3 Cu, 5 Mo, 8 Fe, 21 Cr; Ni |
| Lead | 99.9 Pb |
| Platinum | 99.9 Pt. |
| Gold | 99.9 Au |
| Silver | 99.9 Ag |
| Tantalum | 99.9 Ta |
| Titanium | 99. Ti |
| Stainless Steel: | |
| Type 304 | 0.08 C max., 9 Ni, 18 Cr; Fe |
| Type 310 | 0.25 C max., 20 Ni, 25 Cr; Fe |
| Type 316 | 0.1 C max., 2.5 Mo, 12 Ni, 17 Cr; Fe |
| Type 317 | 0.1 C max., 3 Mo, 9 Ni, 19 Cr, Fe |
| Type 410 | 0.15 C max., 13 Cr; Fe |
| Type 430 | 0.12 C max., 17 Cr; Fe |
| Type 446 | 0.35 C max., 27 Cr; Fe |
| Worthite | 0.07 C max., 3 Mo, 3.5 Si, 19 Cr, 24 Ni; Fe |
| Carpenter 20 | 0.07 C max., 0.75 Mn, 1. Si, 2 Mo. 3 Cu, 20 Cr. 29 Ni; Fe |
| Duriron | 0.8 C, 0.7 Mn, 14.5 Si; Fe |

### References

1. M. G. Fontana. *Ind. Eng. Chem.*, **41**, No. 8, 77A (1949) Aug.
2. James A. Lee. Materials of Construction for Chemical Process Industries, 1st ed. p. 233. New York, McGraw-Hill Book Co., Inc.
3. H. O. Teeple. *Corrosion*, **8**, No. 1, 15 (1952) Jan.
4. A. Wachter and N. Stillman. *Trans. Electrochem. Soc.*, **87**, 183 (1945).

## DISCUSSION

**Questions by Paul E. Krystow, Standard Oil Development Co., Linden, N. J.:**

1. Since the volume of acid used in the tests was so small, what effect, if any, is there on the corrosion rate through the depletion of acidity and by the accumulation of corrosion products? According to the work of Calcott, Whetzel and Whittaker, at least 55 ml of solution is required for each square inch of metal surface exposed.
2. In conducting corrosion tests of acids at high temperatures considerable silica is leached out from the glassware. Is it possible for this silica to form a deposit on the metal surface and retard corrosion particularly since some investigators have found such deposits during their investigations of passive films on stainless steel?

**Reply by R. F. Miller:**

1. Although the volume of liquid in the glass tubes is quite small this is not a particular disadvantage for acids of appreciable concentration, because considerable corrosion can occur before the solution is depleted. For example, in a one-day test of stainless steel in 12 ml of 4.6 percent formic acid at 170 degrees C, a corrosion rate of 140 mils/yr was obtained. This would result in a reduction in the formic acid concentration from 4.6 percent to 3.5 percent.
2. No such deposits were observed in these tests. We would not expect silica to have a significant effect on corrosion rate in the actively corroding systems investigated.

**Questions by Lewis W. Gleekman, Sherritt Gordon Mines, Ltd., Ottawa, Ont.:**

In view of the testing procedure followed, did the authors attempt a study of the corrosion products as a function of alloy content or corrodent? The isolated system used for each alloy would seem ideal for such a study.

**Reply by R. F. Miller:**

We have not made studies of this type.

**Question by W. B. Brooks, Dow Chemical Company, Freeport, Texas:**

The data on copper are quite intriguing. Can you offer any observations on its film-forming characteristics under these conditions as compared to more normal conditions of temperature and pressure?

**Reply by R. F. Miller:**

No observations were made regarding detailed aspects of film formation. No unusual films or coatings were noted by visual examination.

# Porcelain Enamels and Ceramic Coatings, Prime Inhibitors of Metal Corrosion*

By DWIGHT G. BENNETT

## 1. Introduction

THE MODERN DAY uses of porcelain enamels and ceramic coatings as engineering materials have been developed from an ancient background of interest and beauty. In the middle ages itinerant metalsmiths and craftsmen ranged through Europe with charcoal furnaces plying the art of enameling on iron, silver and gold, a skill which was handed down from father to son. Dukes and barons and kings and queens were their customers.

It was inevitable that the protective properties of glassy enamel on easily corrodible iron would soon come to be recognized. This was closely followed, as the stately pace of old history is measured, by the definite start of an enameling industry. Cooking utensils and plumbing ware, it appears, received early attention. From that time on the art and science of porcelain enameling progressed, first steadily and then with constantly increasing tempo.

## 2. The Durable Nature of Porcelain Enamels

It is really not hard to understand why porcelain enamels and ceramic coatings are able to resist so well the ravages of time, temperature and corrosive media. They are essentially formulated from metal oxides and silicates which have emerged from molten magmas in their final and most stable forms. In their processing, the materials noted are blended to fit the intended metal thermal expansionwise and to fuse to a dense, impervious layer at some temperature higher than that of intended service. In the case of conventional porcelain enamels that spread between fusion and service temperatures is, in general, quite large. In the case of high temperature resistant ceramic coatings the spread is, perforce, much smaller.

## 3. Enamel Properties at Room and Slightly Elevated Temperatures

Even though high temperature corrosion is the problem of stated and current interest it is useful to review some of the properties of enamel at lower and very common, temperature levels.

3.1. **Appearance:** As any artist, designer or salesman will attest, people today react very strongly to the outward appearance of things. Here porcelain enamel more than holds its own. It presents a smooth lustrous surface that may range from milk white to any color or shade of color desired. Because these colors stem from stable oxides fused into the glass they will not fade. Furthermore the surface is hard and glass smooth and can be cleaned with a wipe of a damp cloth.

★ A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

DWIGHT G. BENNETT—Research Professor, Department of Ceramic Engineering, University of Illinois. He holds a BS in ceramic engineering from University of Illinois in 1930 and subsequently did graduate work at University of Pittsburgh. He has worked at Geo. D. Roper Corp., A. O. Smith Corp., Metal and Thermit Corp., 1930-31; Mellon Institute, 1931-43. He has been chairman, Enamel Division, American Ceramic Society and chairman of the society's Pittsburgh and Chicago Sections. He is a member of several Greek letter professional groups and co-holder of several patents in the high temperature ceramics field.

### Abstract

Some of the pertinent background of present day developments in protecting metal from corrosion by means of ceramic coatings is reviewed. Test methods are presented and the evaluation of selected tests discussed. Some examples of coating effectiveness and areas in which coatings could be used to advantage are presented.

3.2. **Physical Properties:** A porcelain enamel is highly resistant to abrasion. A test can scarcely be found that will commonly relate this property to an equivalent one for the much softer organic finishes. As various tests in bending and tension have shown, porcelain enamel measurably strengthens the metal shape to which it is applied. It is not commonly known (but nevertheless established) that the glass will flex with ordinary iron or steel up to their proportional limits.

A great deal has been learned about ways to promote the physical durability of porcelain enamel. With planned and controlled thermal stresses between the coating and the metal and with proper thickness of application the coating will withstand a surprising amount of abuse involving thermal and mechanical stresses.

3.3. **Chemical Properties:** From a utilitarian point of view the chemical properties of porcelain enamels are exceedingly important. Years of test "in situ" have shown how well architectural enamels withstand environments that range from moist, salt laden sea air to the gas contaminated air of industrial cities.

The substantial acid and alkali resistance of selected enamels is being utilized to an ever growing extent in the food and beverage, chemical and laundry industries. In home cooking and household use porcelain enamels withstand baking temperatures, boiling water, hot fruit acids, soap and detergents. Millions of hot water heaters utilize porcelain enamels as an inert inner liner.

With the advent of titania type enamels it is now common procedure to turn out ware that will show not more than 0.0009 gram per square inch loss when exposed to 6% boiling citric acid for 2½ hours.

### 4. Development of Ceramic Coatings' Resistant to High Temperatures

The long established art and, in modern times, sound technical status of porcelain enameling formed a natural basis for the development of high temperature resistant ceramic coatings. In this development at least two factors were exceedingly favorable. In the first place the outward appearance of the coating was of no importance whatsoever. In the second place the potentially great value of such coatings in protecting basic and expensive equipment well justified a broad investigation of almost any and all promising coating ingredients regardless of their cost.

Some of the very first work on such coatings was initiated by the armed services at the United States Bureau of Standards and the University of Illinois about ten years ago. Since that time similar research and development work has been taken up by other research institutions, universities, frit companies and aircraft manufacturers. The actual commercial application of high temperature resistant ceramic coatings is under way with various industrial plants participating.

Throughout the course of this work a very considerable amount of technical information has been accumulated in the form of reports and research papers. In fact its volume is now so large that any attempt to present an adequate list of references would be beyond the scope of this paper. However, it can be said that the Armed Services Technical Information Agency is able to reproduce such data for qualified recipients. In a more general way, the U. S. Department of Commerce, through its Office of Technical Services, is preparing to make such material available to the public. Also, many libraries, university and otherwise, are serving as depositories for it.

### 5. Some Things High Temperature Resistant Ceramic Coatings Will Do

Such coatings, as has been shown in the preceding section, have been developed step by step to serve various unique and particular needs in the way of protecting heated metal from its environment. The following list of items is brief but it should be kept in mind that each has been the subject of painstaking research and various reports. The order is arbitrary since a property of first importance in one application might be of little or no interest in another.

Specific forms of ceramic coatings will:

1. Reflect radiant energy
2. Effectively retard metal oxidation
3. Strongly inhibit intergranular corrosion
4. Withstand acids, including fuming nitric acid
5. Resist molten metals
6. Improve tensile, stress rupture and fatigue properties of heated metals

The summary above is supplemented by various tables and figures included in this article. They have been taken from sundry reports and research files both past and present.

Table 1 shows the present status of some work now in progress at the University of Illinois.

A considerable number of coatings either developed for, or applicable to low alloy steels are being systematically tested and classified. It may be noted that the order of rating takes account of

1) the ability of the coating to protect the metal at high temperature,

2) the lower firing time and temperature and

3) the resistance to water quenching.

This table serves to point out that the selection of a ceramic coating might be based on one or more of at least four properties,

a) resistance to high temperature,

b) permissible firing temperature,

c) resistance to severe thermal shock or,

d) ability to resist acid attack.

Not shown in the table, but a good illustration nevertheless would be the case of University of Illinois high temperature resistant ceramic coating No. 250-2 which is now undergoing tests (in a "cold finger" reflux condenser of modified ASTM standard A 262-44T type) for its resistance to fuming nitric acid at 160 degrees F. After 192 hours of test the attack on the coating is scarcely measureable. In some specific application such acid resistance might easily outweigh maximum resistance to high temperature.

Table 2 contains data similar to those in the first table except that they were obtained on coatings developed for stainless steels and high alloy metals. The same order of classification is followed except that in a few cases when all other properties were equal coatings were rated on the quality of their acid

**TABLE 1**

**Some Significant Properties of Selected Ceramic Coatings Developed for Low Alloy Steels at University of Illinois**

| Coating No. | Application Weight (gms/ft²) | Best Min. | Firing °F. | Protects Metal Up To (°F.) | Shock Resist.[1] Up To (°F.) | Acid Resist.[2] PEI Class |
|---|---|---|---|---|---|---|
| 418-26 | 35-40 | 6 | 1600 | 1400 | 1200 | .... |
| 347-1 | 50-55 | 6 | 1650 | 1400 | .... | AA |
| 418-13 | 42-45 | 8 | 1650 | 1400 | 1000 | C |
| 410-1 | 40-45 | 6 | 1700 | 1400 | .... | A |
| 485-1 | 42-46 | 6 | 1650 | 1300 | <1100 °F. | A |
| 285-1 | 40-45 | 6 | 1750 | 1300 | < 900 °F. | B |
| 428-1 | 40-50 | 6 | 1400 | 1200 | .... | B |
| 424-1 | 45-50 | 6 | 1600 | 1200 | .... | A |
| 474-1 | 42-45 | 6 | 1650 | 1200 | 1300 | C |
| 32-50 | 45-50 | 6 | 1650 | 1200 | 1000 | C |
| 285-30 | 40-45 | 6 | 1700 | 1200 | 1000 | D |
| 462-1 | 42-46 | 6 | 1750 | 1200 | <1200 | AA |
| 327-1 | 30-40 | 4½ | 1900 | 1200 | <1200 | AA |
| 296-1 | 30-40 | 4 | 1950 | 1200 | .... | AA |

[1] cf Sec. 6, 2, 1.b of this paper. Thermal shock testing by subjecting each of 6 coated specimens to 10 cycle of 20 min. heating at test temp., followed by immersion in water at room temperature.
[2] "Test for Acid Resistance of Porcelain Enamels," Part I. Flatware. A standard of The Porcelain Enamel Institute.

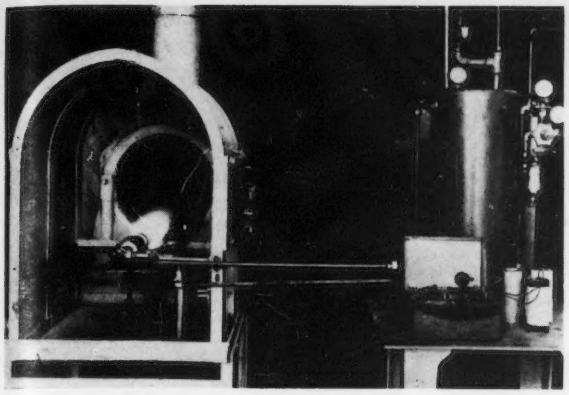

Figure 1—Gasoline fired thermal shock torch in operation.

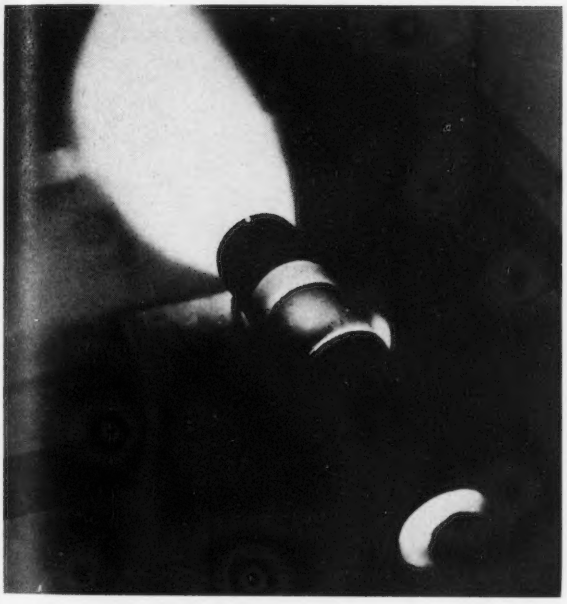

Figure 2—Detailed view of specimen on gasoline torch burner stand showing band of glow where top coat was brushed away before the maturing fire.

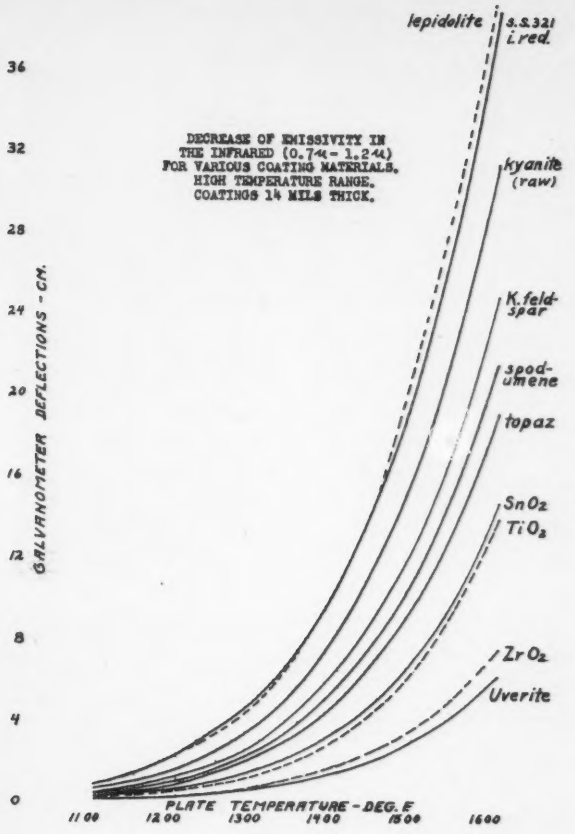


Figure 3

resistance. As might be expected, due to the better heat stability of the metals used, it was possible to develop coatings showing higher values in all classifications.

It should be noted that a column added in Table 2 shows the various alloy metals which were used. Due probably to rates of metal oxidation and coating fusion during the maturing fire ceramic coatings are definitely selective with regard to the metals on which they should be used.

Before passing on from consideration of tabular type data it should be noted that under a research grant from industry some work on the resistance of porcelain enamels and ceramic coatings to such molten metals as lead, zinc and tin is being carried on in the Department of Ceramic Engineering, University of Illinois. As a matter of cooperative interest a number of ceramic coatings of the types shown in Tables 1 and 2 are being included in these tests and with encouraging results. When completed, the results of the work will be available to those who may be interested.

Figures 1 and 2 show respectively an aviation gasoline fired torch in operation and the glow sup-

**TABLE 2**

**Some Significant Properties of Selected Ceramic Coatings Developed for Stainless Steel and Other High Alloy Metals at the University of Illinois.**

| Coating No. | Metal[1] Type | Application Weight (gms/ft²) | Best Min. | Firing °F. | Protects Metal Up To. (°F.) | Thermal Shock[2] Resistant Up To (°F.) | Acid Resist[3] PEI Class |
|---|---|---|---|---|---|---|---|
| 456-8 | IN | 20-30 | 6 | 1850 | 2000 | 1700 | .... |
| 456-4 | IN | 20-30 | 6 | 1850 | 2000 | <1700 | .... |
| 456-3 | 321 | 15-30 | 5 | 1800 | 1900 | 1700 | .... |
| 456-6 | SS | 20-30 | 6 | 1800 | 1900 | 1700 | .... |
| 418-7 | IN | 14-16 | 10 | 1800 | 1900 | 1700 | .... |
| 452-1 | IN | 25-30 | 6 | 1750 | 1800 | 1700 | A |
| 456-1 | 321 | 15-30 | 6 | 1750 | 1800 | 1700 | C |
| 353-2 | IN | 15-20 | 6 | 1750 | 1800 | 1700 | .... |
| 454-1 | IN | 25-30 | 6 | 1775 | 1800 | 1700 | AA |
| 455-1 | SS | 25-30 | 6 | 1775 | 1800 | 1700 | C |
| 458-1 | IN | 20-30 | 6 | 1800 | 1800 | 1700 | C |
| 418-1 | SS | 15-18 | 6 | 1800 | 1800 | 1600 | AA |
| 451-3 | 430 | 17-20 | 6 | 1800 | 1800 | .... | .... |
| 423-1 | 321 | 15-20 | 6 | 1850 | 1800 | .... | .... |
| 418-12 | SS | 14-16 | 6 | 1800 | 1700 | 1700 | C |
| 327-1 | SS | 15-18 | 6 | 2100 | 1400 | 1700 | AA |

[1] IN = Inconel. SS = 18-8 type stainless steels. Other steels by AISI No.
[2] cf Sec. 6, 2, 1.b of this paper—Test for Thermal Shock.
[3] A standard test of the Porcelain Enamel Institute.

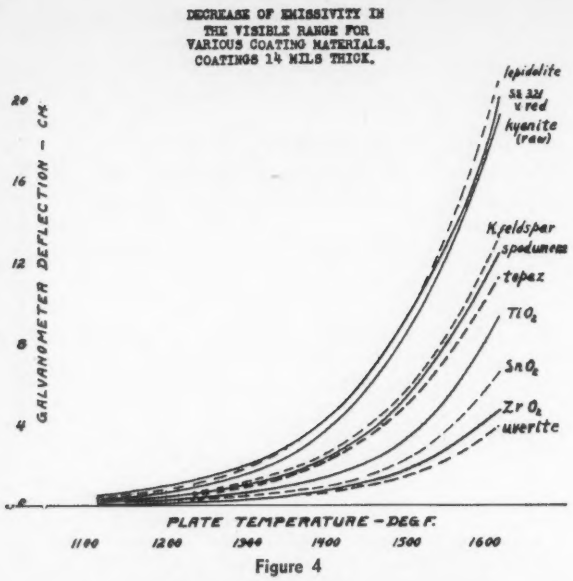


Figure 4

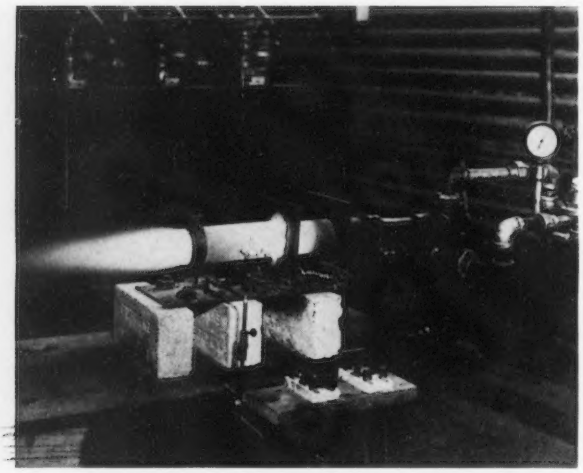

Figure 5—Test stand for the determination of transient state temperature lags and the reduction of equilibrium skin temperatures produced by ceramic coatings.

pression obtained with a ceramic coated flame tube. Figures 3 and 4 show the effectiveness of various coating materials in reflecting radiant energy in the infrared and visible wave bands. Figure 5 shows a high pressure gas-air torch in operation. In Figure 6 is shown the considerable reduction of transient and steady state temperatures possible to obtain by internally applying a ceramic coating to a flame tube. A method for measuring the oxidation resistance of ceramic coatings and the high order of protection possible to obtain are shown in Figures 7 and 8. In Figure 9 is shown the completely destructive effect of heating bare ingot iron and low carbon steel for 72 hours at 1600 degrees F and the effective protection given by ceramic base coats and such base coats with heat reflective top coats applied over them. Figure 10 shows equipment for heating and tensile testing sheet metal specimens prepared according to ASTM specification E8-E6. Figures 11 and 12 show the improvement given by ceramic coatings to No. 347 stainless steel and 1020 low carbon steel which

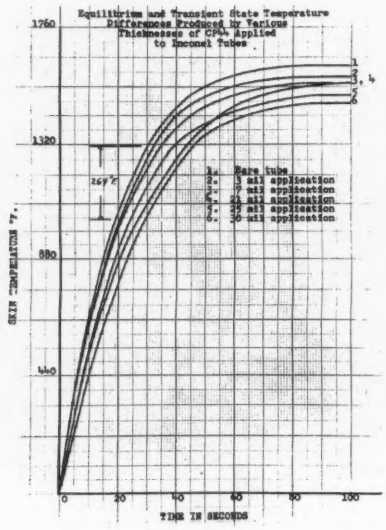
Equilibrium and Transient State Temperature Differences Produced by Various Thicknesses of CP-4 Applied to Inconel Tubes
SKIN TEMPERATURE °F.
TIME IN SECONDS
1. Bare tube
2. 3 mil application
3. 7 mil application
4. 21 mil application
5. 25 mil application
6. 30 mil application
267°F.

Figure 6

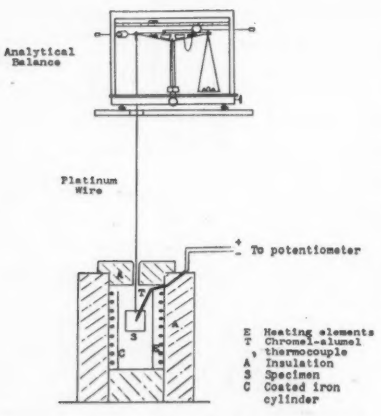


Figure 7—Sketch of method and apparatus for measurement of the oxidation of enamel iron.

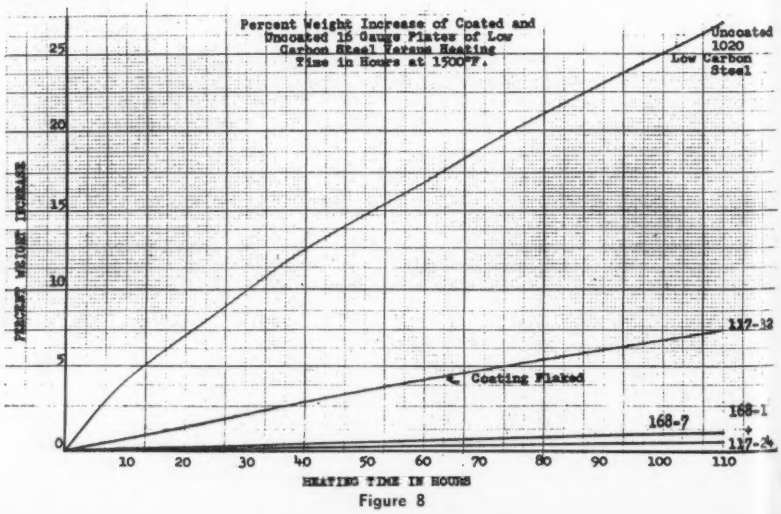
Percent Weight Increase of Coated and Uncoated 16 Gauge Plates of Low Carbon Steel Versus Heating Time in Hours at 1500°F.
PERCENT WEIGHT INCREASE
HEATING TIME IN HOURS
Uncoated 1020 Low Carbon Steel
117-32
Coating Flaked
168-7
168-1
117-24

Figure 8

were long heated then tensile tested. Figure 13 shows how the improvement given by a ceramic coating carries on even when the steel (No. 347) is broken in tension at 2000 degrees F. Figures 14 and 15 show the improvement in fatigue strength and fatigue life imparted to No. 347 steel by a ceramic coating and how the improvement is sustained after extended heating for 10 hours at 1800 degrees F. Finally, Figure 16, which represents some work done at Cornell Aeronautical Laboratories and described in Wright Air Development Center Technical Report 52-77, (April, 1952) shows the improvement in creep and rupture strength obtained by use of a ceramic coating on a low alloy steel. Test temperatures were 1200 and 1400 degrees F. The curves for the uncoated steel were located originally by means of adequate data points as shown in Figures 7 and 8 of the WADC report.

### 6. Present Status of Ceramic Coatings

6.1. **Current Research:** The peak in research on ceramic coatings has not yet been reached. Various universities, research institutions and sections of industry have teamed up, with a valuable "assist" from forward looking agencies of the armed services, to make one advance after another. As a part of this, one significant change in approach should be recognized. Early research, as is probably always the case, more or less sought to make the application fit the existing or available materials. Now, however, the viewpoint is much more toward making the materials fit the existing application, even if it means developing new materials. This is not merely a figure of speech. Little known, or at least little used oxides, borides, hydrides, silicides and metal-ceramic composites are being carefully investigated.

In keeping with the statements made above current research is, in general, being directed toward specific objectives such as:

a. Determinations of the effect of ceramic coatings on the physical properties and durability of selected stainless steels and low alloy steels. Emphasis is placed on fatigue and stress rupture testing and metallurgical studies, in such determinations.

Stainless steels receiving the greatest attention tend to be of non-strategic type. The low alloy metals are of increasing interest. The optimum combination would be a steel with just enough alloying elements to give high temperature strength, protected from corrosion by a suitable ceramic coating.

b. Development of coatings of maximum stability in high temperature service. Such coatings may be of the glassy type but free of certain fluxes and other components of volatile and highly reactive nature or they may be of a metal-ceramic type wherein applied heat serves to sinter their components into a dense, stable, and adherent layer.

c. Development of relatively opaque, somewhat crystalline ceramic base coats capable of protecting the metal from oxidation and reflecting a considerable amount of radiant heat, as well.

d. Development of specific coatings for such metals as molybdenum, which has very good high temperature properties if protected from oxidation; and titanium, which appears to be capable of good performance at moderately high temperatures if protected from carbon and various alloying gases.

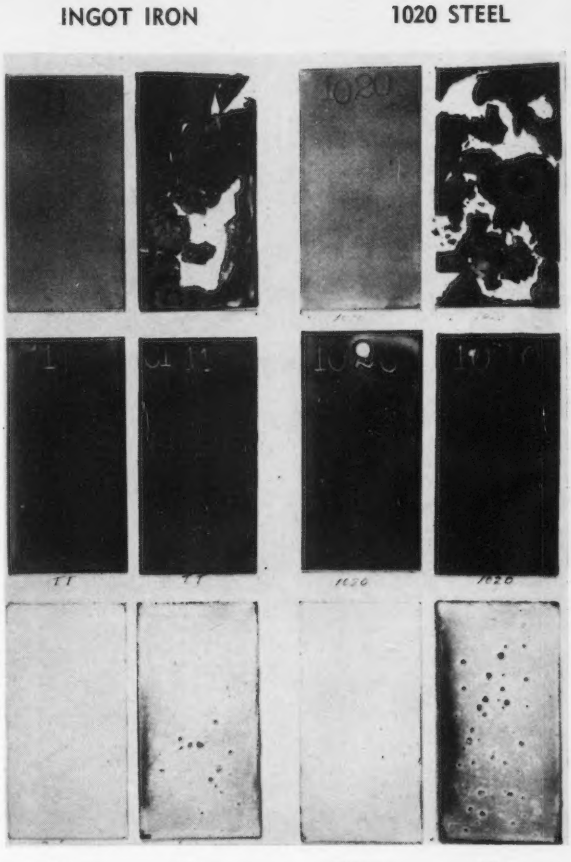


**Figure 9—Effect of heating uncoated and ceramic-coated ingot iron and 1020 low carbon steel for 72 hours at 1600 degrees F. Top row: Uncoated. Middle row: Ceramic coating No. 285-1. Bottom row: Top coat No. 117-23 over No. 285-1.**

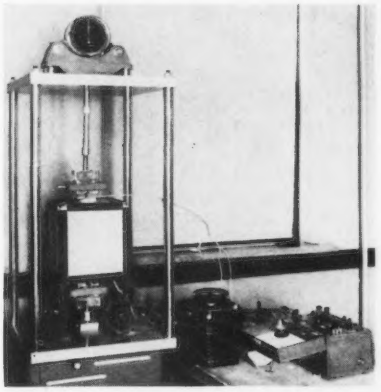

**Figure 10—Apparatus for determining tensile strength of coated and uncoated metal specimens at elevated temperatures.**

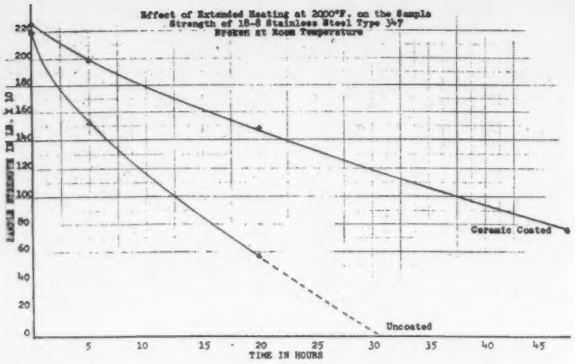
Effect of Extended Heating at 2000°F. on the Sample Strength of 18-8 Stainless Steel Type 347 Broken at Room Temperature
Ceramic Coated
Uncoated
TIME IN HOURS

Figure 11

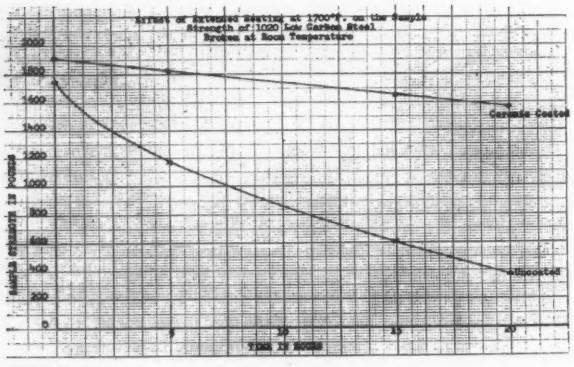
Effect of Extended Heating at 1700°F. on the Sample Strength of 1020 Low Carbon Steel Broken at Room Temperature
Ceramic Coated
Uncoated
TIME IN HOURS

Figure 12—Effect of extended heating at 1700 degrees F on the sample strength of 1020 low carbon steel broken at room temperature.

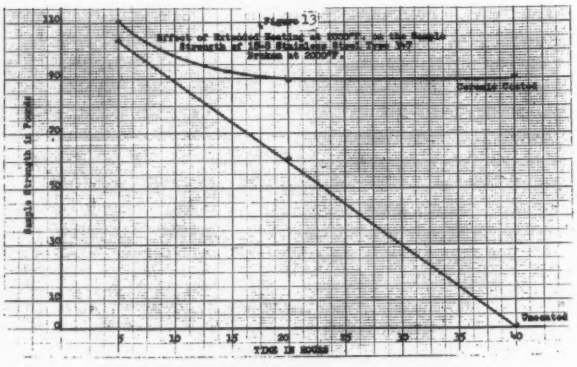
Figure 13
Effect of Extended Heating at 2000°F. on the Sample Strength of 18-8 Stainless Steel Type 347 Broken at 2000°F.
Ceramic Coated
Uncoated
TIME IN HOURS

Figure 13—Effect of extended heating at 2000 degrees F on the sample strength of 18-8 stainless steel Type 347 broken at 2000 degrees F.

**6.2. Test Methods:** Evaluation of high temperature resistant ceramic coatings is, in various ways, a specialized procedure. In the first stage of their development the microscope, the electron microscope, the x-ray and any or all of the other ultra tools of science are used as needed. In the intermediate stage, some tests parallel quite closely those used for more conventional porcelain enamels. Others, as might be expected, differ greatly. As a final step, actual testing for performance in service must be carried out.

It would be proper to consider here only the significant intermediate tests that are gaining uniform recognition.

**6.2.1. Extended Heating:**

a. Static test. Using a box type furnace, alternately heat a coated flat specimen to 200 degrees F above the intended temperature of service and cool it to room temperature. Periods of heating, soaking and cooling are to be repeated in cyclic fashion for 5 days (120 hours) with a final soaking period of 80 hours. Four or more specimens per coating are to be tested and examined visually and microscopically.

b. Dynamic test. A small, completely coated metal cylinder is suspended in a flame tube and heated, in two 8-hour periods, by enveloping flames to the intended service temperature. Six specimens per coating are used and examined visually and microscopically. The indentation method may be used to check adherence.

**6.2.2. Thermal Shock Test:** Using a box type furnace, heat 6 coated flat plate specimens per coating to the intended service temperature for 20 minutes. Quench in water at room temperature. Subject each specimen to 10 such cycles. Examine them visually and microscopically.

**6.2.3. Adherence Test:** This test shall be made in conformity to the Porcelain Enamel Institute (Bulletin T-17) "Test for Adherence of Porcelain Enamel to Sheet Metal."

In this test, coated flat plate specimens are uniformly indented in a ball point press and readings of coating continuity taken with an adherence meter which samples the deformed area with 169 electrically conducting needlelike probes arranged in a hexagonal pattern.

**6.3. Applications:** It is impossible to draw many conclusions in regard to use limits of a material which is developing so rapidly. An idea, however, of the present scope of application of ceramic coatings may be gained by considering some known facts.

Development of ceramic coatings for industrial as well as national defense uses has been taken up by important segments of industry. These include the manufacturers of porcelain enamel, frits, various independent enameling plants and corresponding processing divisions of some large and diversified corporations. Several plants are in production on defense items and various units incorporating heat resistant ceramic coatings are coming off production lines. These include nozzle boxes for gas turbines, exhaust stacks, flame tubes and heat exchangers.

Some plants, tooled for production of these items, have indicated they are now in a position to do commercial work as well.

In such undertakings some of the lessons in teamwork learned in World War II are being put to good use. There is close and effective cooperation among

the research groups which contributed fundamental coating formulation, the frit manufacturers who adapt them to commercial use and the industrial plants prepared to apply them.

Many of the items being considered are indicated in a general way in Sections 5 and 7 of this paper. They cover a wide range wherein metal is subject to deterioration by heat or other corrosive media. It is quite probable, however, that some of the greatest financial savings to be gained by use of ceramic coatings will be made in areas where ordinary uncoated steel is used at moderately high temperatures and has, heretofore, been replaced frequently as a matter of course.

6.4. **Controls:** More and more, the sustained development of all ceramic coatings is falling into an effective pattern. The mechanics of information exchange and dissemination get better. The Porcelain Enamel Institute is a control center for industry. The armed services through WADC have held symposia and directed testing procedures toward a uniform pattern. The American Society for Testing Materials, through its committee C-22, is working to broaden the useful scope of porcelain enamels and ceramic coatings and to advance carefully considered tests to a tentative standard stage.

## 7. Porcelain Enamels and Ceramic Coatings In Relation to Engineering Design

This topic is certainly of current interest and one on which much information has very recently become available. In a recent survey directed to 700 agencies representing research and development and widely diversified industry. Committee C-22 of the ASTM undertook to establish both general and particular areas of interest in porcelain enamels and ceramic coatings as engineering materials. The high percentage of replies was almost unprecedented. It became apparent that the possible useful range of application of the materials was practically unlimited. Ten suggested topics or areas covering the relation of ceramic coatings to chemicals, abrasion, high temperature corrosion, physical and thermal shock and their use on nonferrous metals received strong and somewhat diversified support with, as might be suspected at this time, the greatest interest being shown in resistance to high temperature corrosion.

An invitation was extended to the recipients of the survey form to indicate other topics of interest to them. Their response was startling. More than 150 additional topics of general and particular interest were suggested.

There is perhaps no better way to emphasize the potential role of porcelain enamels and ceramic coatings in engineering design than to list some of the many significant suggestions that were received.

7.1. The resistance of ceramic coatings to:
- a. hot specific chemicals
- b. molten metals as lead, zinc, aluminum
- c. high velocity gases
- d. vibration
- e. gas penetration

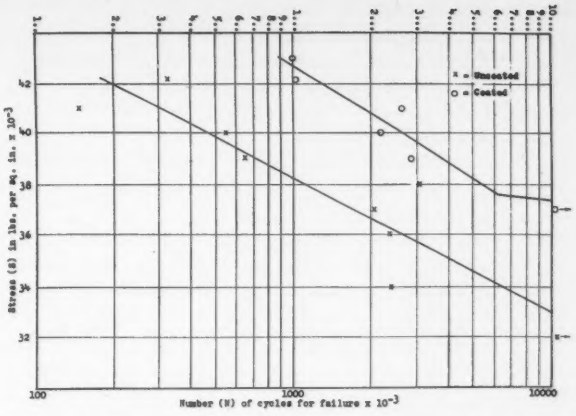


**Figure 14—S-N diagram showing the effect of coating No. 285-1 on specimens of stainless steel Type 347 annealed for 10 minutes at 1800 degrees F.**

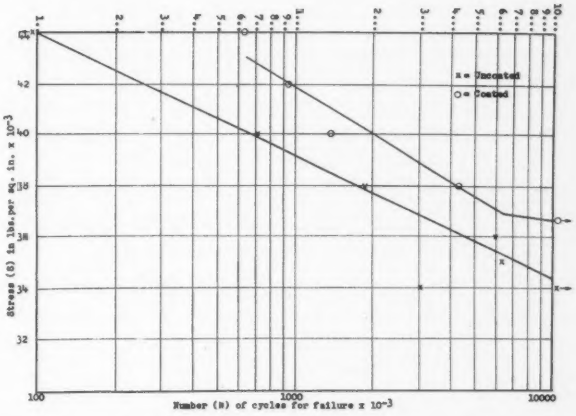


**Figure 15—S-N diagram showing the effect of Coating No. 285-1 on specimens of stainless steel Type 347 subjected to extended heating for 10 hours at 1800 degrees F.**

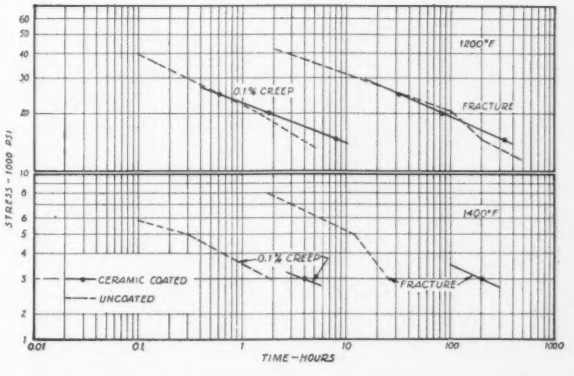


**Figure 16—(Figure 19 in Wright Air Development Center Technical Report 52-77) Creep and rupture strength of ceramic coated 0.050-inch sheet, 600-lb. heat of 3Cr-1Mo-Ti-B steel.**

- f. long heating in particular atmospheres
- g. electron bombardment

7.2. Their use:
- a. in fluid conduits to reduce friction

b. in bearings for high temperature use
c. in sewage and water treatment
d. on structural steel, bridgework and building components
e. for thermal insulation and reflection of radiant heat

These are only a few of the possible applications suggested but they will serve to indicate the wide range of potential use.

It should be interesting to point out that in preceding sections the direct applicability of porcelain enamels and ceramic coatings to many of the noted uses is indicated. They would very probably serve in most of the others with only a reasonable amount of preliminary research and development involved.

### 8. Summary and Conclusions

**8.1.** It is shown that porcelain enamels were known in very early times and that much of their development and increasing economic importance can be traced through recorded history.

**8.2.** Their durability and wide range of usefulness in protecting metal at room and considerably higher temperatures were found to be well established. They thus formed a natural basis for the development of high temperature resistant "ceramic coatings."

**8.3.** The modern day research and development status of ceramic coatings is outlined with examples of some of their applications being given.

**8.4.** In discussing these inorganic coatings in relation to engineering design their probable usefulness in many diverse fields of metal protection is brought out.

**8.5.** All work to date seems to point convincingly toward a widespread adoption of porcelain enamels and ceramic coatings to combat metal deterioration due to such things as heat, abrasion, vibration, or close contact with corrosive fluids and gases of many kinds.

### 9. Acknowledgment

The review and clearance of this paper by the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, under whose sponsorship most of the data shown were accumulated, is appreciably acknowledged. They also kindly permitted the use of Figure 16 which represents work done at the Cornell Aeronautical Laboratories, Ithaca, New York.

## DISCUSSION

**Question by Louis M. Nieliwocki, 3210 Allison Ave., Port Arthur, Texas:**

Has any work been done to determine the effectiveness of these ceramic coatings on carburization of stainless steel?

**Reply by Dwight G. Bennett:**

Yes! Some very good work has been done. I would like to call your attention to the following: National Advisory Committee for Aeronautics, Technical Note 2572, "Ceramic Coatings for Prevention of Carbon Absorption in Four Heat-Resistant Alloys," by Joseph W. Pitts and Dwight G. Moore, National Bureau of Standards. The authors applied ceramic coatings to specimens of Inconel and stainless steel of AISI Types 304, 321 and 347. The coated specimens were then box carburized for 4 hours at 1350 degrees to 1650 degrees F. It was concluded that the coating seals the samples of the alloy from carburizing gases and thus prevents carbon pick-up and resulting precipitation of carbides at or near the grain boundaries. The paper contains a series of photomicrographs supporting that conclusion.

**Question by Edward D. Weisert, Haynes Stellite Co., Kokomo, Ind.:**

How could the decrease of thickness of the ceramic coating from two to a half-thousandth on the turbine blade exposure be accounted for?

**Reply by Dwight G. Bennett:**

Any erosion from the rapidly moving gas stream which probably contained very fine solid particles would tend to decrease the coating thickness. Other work, however, on thermal shock spalling has shown that while rapid temperature changes will tend to cause the outer layers of some ceramic coatings to flake off there will remain a thin, limiting, layer of coating which is very resistant to spalling.

# Materials for Central Station Pumps*

By J. B. GODSHALL

AS RECENTLY as 15 years ago, most pumps for boiler feedwater for central-station applications were constructed with bronze impellers and carbon steel casings. Cast iron casings generally were used for the lower-pressure applications.

Continual increases in temperature, pressure and particularly in the purity of feedwater resulted in an alarming increase in pump maintenance and pump failures by corrosion-erosion. Independent studies of this problem by the operators, pump manufacturers and various technical groups led to certain conclusions and recommendations which have been published in the 1941-1942 report of the Boiler Auxiliaries Subcommittee of the Prime Movers Committee, Edison Electric Institute, New York City and later in "Feed-Pump Symposium," *Mechanical Engineering*, December, 1946.

### Materials Used for Feed Pumps

Subsequent field results and manufacturing experience have substantiated the importance of using materials which will resist corrosion-erosion by boiler feedwater. In the light of present-day experience, the conclusions could be restated and expanded as follows:

1. It is rarely feasible to reduce corrosion by modifying the water. The increasing use of ammonia to control deposition of iron oxide should not be confused with water conditioning for the prevention of corrosion.

2. Materials must be used which will resist corrosion-erosion by any central-station feedwater.

3. Cast iron, carbon steel and bronze are not sufficiently resistant to corrosion-erosion by typical central-station feedwater to warrant recommending these materials for general use. Low-alloy steel containing one percent chromium has shown excellent resistance under favorable circumstances, but it is not sufficiently resistant to warrant its recommendation for all conditions.

4. The use of 5.% chromium-0.5% molybdenum steel substantially eliminates corrosion-erosion. Higher alloy concentrations do not result in any marked improvement over five percent chromium steel. Many studies have shown that if carbon steel is rated at 1, the following table indicates the relative expected service life for different pump materials in typical central-station feedwater:

| Material | Relative Service Life |
|---|---|
| Carbon Steel | 1 |
| 1.% Chromium Steel | 10 to 90 |
| 5.% Chromium-0.5% Molybdenum Steel | 100 |
| 13.% Chromium Steel | 100 to 105 |
| 18/8 Stainless Steel | 100 to 150 |

★ A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

**J. B. GODSHALL**—Metallurgist for the Cameron Division of Ingersoll-Rand Company, he has as one of his responsibilities materials engineering for pumps as related to their corrosive environments. Starting in the analytical laboratory of Ingersoll-Rand in 1926, he became chief chemist in 1930. He has been in his present position since 1941. He is a member of numerous technical organizations, including NACE and has been active in committee work and as an officer of engineering groups.

### Abstract

Increased temperature, pressure and purity of central-station feedwater causes corrosion-erosion in feed pumps. Studies by operators, pump manufacturers and technical groups have led to certain conclusions: 1. Reducing corrosion by modifying the water is rarely feasible. 2. Materials must be used which resist corrosion-erosion. 3. Cast iron and carbon steel are generally unsuitable. 4. Five percent chromium steels prevent corrosion-erosion. Higher alloy concentrations do not provide a marked improvement. Relative service life is about 1 for iron and steel, 10 to 90 for 1.% chromium steel, 100 for 5.% chromium steel, 100 to 105 for 13.% chromium steel and 100 to 150 for 18/8. General use of chromium steels presents manufacturing problems. Clearances must be adjusted and different materials and/or hardnesses are important to prevent seizure. Preheating and stress-relief annealing are important after welding. Stainless or "K" Monel shafts are recommended.

Heater drip pumps need all-bronze or 13.% chromium steel construction if dissolved gases are present. If there is no contamination, or if the temperature is low as in the case of condensate pumps, iron or steel casings with bronze impellers are used. Circulating pump materials vary with the water quality.

Cast iron casings and bronze impellers are typical for fresh water. For sea and harbor waters all-bronze construction is desirable. With polluted harbor waters, stainless steel impellers in bronze casings are sometimes necessary. Commercial considerations sometimes dictate the use of cast iron casings for very large circulating pumps. For the corrosive applications, Monel or stainless shafts are recommended to prevent failures by corrosion fatigue.

The suitability of 5.% chromium-0.5% molybdenum steel has now been established firmly by the excellent condition of rotor parts which are approaching 100,000 service hours and by casings with over 50,000 hours handling aggressive feedwater which caused serious corrosion-erosion of carbon-steel casings in as little as 500 hours. The only instance of difficulty with this type of material involved a feedwater that was not deaerated. The presence of other corrosive constituents, such as the addition of corrosive chemicals on the suction side of the pump, would be equally

objectionable. Fortunately, such practices are becoming rare in central-station applications.

5. Shells for barrel-type pumps are a notable exception. Mechanical, commercial and manufacturing considerations dictate the use of high-quality, carbon-steel forgings. Because extremely high velocities do not occur in the shell, corrosion-erosion is rarely a problem in this part. As a precaution, a stainless inlay is desirable to protect all gasket joints of the shell which seal against a high pressure differential. In addition, a stainless facing on the discharge head is helpful in preventing corrosion-erosion where the head forms the end closure of the liquid area of the pump. Carbon steel forgings which are protected in this manner are entirely suitable, and are more economical than alloy-steel forgings which would have greater resistance to corrosion-erosion.

6. The use of heat-treated 13.% chromium steel, or heat-treated K-Monel is recommended for the pump shafts. Machining stresses must be relieved in the heat-treated 13.% chromium steel in order to manufacture a straight shaft. K-Monel is much less sensitive in this respect. Because the coefficient of expansion of K-Monel is greater than that of the chromium-steel impellers, the K-Monel shaft provides an excellent means for maintaining a tight fit at the impeller hubs.

### Manufacturing Considerations

The change to the general use of chromium steels was not practical without recognition of certain manufacturing problems. Clearances had to be adjusted for the new materials, and different grades of chromium steels, preferably at different hardnesses, are important to prevent danger of seizing at the running fits.

For example, an excellent combination of materials for the balancing device is a balancing drum of forged 13.% chromium steel, heat-treated to 350 BHN, operating in a forged 5.% chromium-0.5% molybdenum steel balancing sleeve, heat-treated to 425 BHN. This provides both different materials and different hardness at the running fit. The same considerations govern the selection of materials elsewhere in the pump, but the practice will vary with different manufacturers because of different pump designs. For instance, some pumps use impeller rings, but others do not.

It should be noted that hardness alone is no assurance that wear will not occur. Furthermore, the harder of two materials at a running fit will not necessarily show less wear than the softer part. Hardness is an important consideration, chiefly from the standpoint of resisting galling or seizing at the running fits. This is particularly important in the event of operating irregularities, such as the pump being run dry, or abrasive foreign solid material being carried by the water into the pump fits.

The fact that conventional 18/8 stainless steel cannot be hardened by heat treatment is one of the major reasons why this grade usually is not recommended for feed-pump parts. Another consideration is the high coefficient of expansion which introduces mechanical problems, especially in large, high-pressure pumps for feedwater applications. Raw material and machining costs are both relatively expensive. The fact that it has been in short supply because of its high-nickel content is an important consideration.

On the other side of the ledger, 18/8 stainless has excellent resistance to corrosion-erosion by all boiler feedwaters. It has excellent foundry characteristics and relatively sound castings usually are obtained. However, foundry defects can occur with all materials. Defects which will not impair the strength of the casting can be repaired very readily by welding.

By comparison, both 5.% chromium-0.5% molybdenum steel and 13.% chromium steel are relatively difficult compositions to handle in the foundry. Furthermore, both materials are relatively difficult to weld because of their air-hardening characteristics. Parts should be preheated to 400 degrees F, and welded with 25.% chromium-20.% nickel, 25-12, 18-8, or rod of the same composition as the castings. The residual stresses produced by welding should be removed by stress-relieving the welded casting at about 1250 degrees F.

In addition to casings and wearing parts, these two chromium steels are used for impellers, channels, diffusors, and miscellaneous small parts. Chromium-steel is not susceptible to the pitting which often occurs with the less resistant materials. Severe pitting of the impellers increases the power consumption through frictional losses. This represents an additional economy in the use of the resistant chromium-steel impellers.

The iron oxide deposits, mentioned in the preceding paragraph numbered 1, can be very objectionable from the standpoint of pump efficiency. In some cases horsepower consumption has been raised as much as 25.% by such deposits. This accounts for the many reports of trouble due to this cause. There is no doubt that the iron oxide ordinarily does not originate in the pump itself but apparently comes from elsewhere in the system and deposits in the pump.

Shaft sleeves must be both hard and corrosion resistant. Chromium-plated, case-hardened, low-alloy steel (such as AISI A8620) shaft sleeves are giving excellent service in the field and are recommended. This combination provides the hardness, wearing quality and corrosion resistance of chromium, supported by the hard surface of carburized and hardened steel which, in turn, is supported by a tough core. The hardness of the chromium plate is over 900 Vickers and the steel is Rockwell C 60, minimum.

Because a high level of surface hardness is essential for shaft sleeves for high-pressure applications, high-carbon grades must be selected if the 13.% or 17.% chromium steels are to be used. The hardenability of these grades of chromium stainless steel is so great that hardening occurs completely through the wall section. The end result is a sleeve which has the disadvantage of being relatively brittle and susceptible to cracking at keyways and spanner wrench slots if subjected to mechanical or thermal shock. The sleeves also are subject to fatigue failures resulting from localized overheating

at the packing area. The resultant surface checking then progresses longitudinally until the sleeve splits.

### Materials for Buffered Feedwaters

Occasionally, a central-station feedwater will be similar to industrial power-plant feedwaters which are almost always well-buffered. In these cases, the pump materials may be selected on the basis of the pH value of the feedwater.

For pH values from 6.5 to 8.5, the use of cast iron casings with bronze rotors is practical. For pH values above 8.5, the use of all iron construction is practical, but copper-base alloys should be avoided.

With intermittent injection of water-treating chemicals on the suction side of the pump, the pH value will usually be well above 8.5 during injection of the chemicals, but will be considerably below 8.5 at all other times. For these conditions, special ferrous materials, including Ni-Resist (a well-known highly-alloyed austenitic cast iron) and both 5.% and 13.% chromium steels are recommended. The material used for a specific part may be selected on the basis of the experience and preference of the manufacturer.

In these less critical applications and lower pressures, it is not unusual to use heat-treated carbon-steel shafts and low-carbon, 13.% chromium steel shaft sleeves hardened to about 375 Brinell. At this lower hardness the brittleness previously mentioned is not encountered.

In the industrial power plant type of application, the use of steel casings may be necessary for the higher pressure applications. The dividing line between low-pressure and high-pressure applications is not a clearly defined one. It will vary with the design of the pump from the standpoint of design stresses and stress distribution. In general, cast iron is suitable up to about 1000 psi and, on this basis, pressures up to 1000 psi logically could be considered low pressures. At higher pressures steel is usually needed for strength and chromium steels usually are required for resistance to corrosion-erosion.

### Auxiliary and Condensate Pumps

Selection of materials for heater-drip pumps is frequently complicated by the presence of dissolved oxygen and/or carbon dioxide in the water. When these gases are present, the use of all-bronze or 13.% chromium steel is desirable. If there is no contamination, or if the water temperature is low as is the case in condensate pumps, iron or steel casings with bronze impellers are preferred for commercial reasons.

Condensate pumps usually operate at temperatures under 100 degrees F. Booster pumps can be considered low temperature primary feed pumps, operating at about 100 to 150 degrees F. Auxiliary pumps in the feedwater system, such as heater drip or heater drain pumps, ordinarily operate at higher temperatures and require resistant materials. The higher temperatures approach that of the boiler feedwater and are the most critical from the standpoint of resistant materials.

### Condenser Circulating Pumps

Materials for the condenser circulating pumps vary with the quality of the circulating water. Cast iron casings and bronze rotors are satisfactory for typical fresh-water applications. Either carbon steel or 13.% chromium steel may be used for the shafts. The latter is preferred for vertical pumps where journals usually are exposed to the liquid being pumped.

For sea water and brackish harbor waters the use of all-bronze construction is desirable. With highly polluted harbor waters the use of stainless steel (AISI Type 309 or 316) impellers in bronze casings is sometimes necessary.

For commercial reasons, cast iron casings are sometimes used for the very large pumps handling sea or brackish waters even when graphitization is certain to occur. This is particularly true for the outer columns of large vertical pumps where the water flow is relatively streamlined and the velocity is low. It is apparent that the rate of graphitization is independent of the section of the cast iron. Therefore, at the same corrosion rate, the percentage reduction in effective area is much less in the relatively heavy sections which are typical in the larger pumps. No arbitrary classification is available to determine how vertical pumps should be classified with respect to "large" pumps. Pumps with discharge sizes 26 inches and over could be considered "large" units. Pumps over 36 inches discharge might well be classified as "very large."

The use of protective coatings is increasing, particularly in vertical pumps where the symmetrical, streamlined outer columns are less difficult to protect. These coatings include both rubbers and plastics. The multilayer type has the advantage of being more uniformly impervious to the liquid provided the original bond is perfect. In the absence of a perfect bond or an impervious coating, localized failure can be very rapid. It should be noted also that it is extremely difficult to protect sharp corners and running fits by the use of any kind of protective coating.

For sea and brackish waters the use of Monel or stainless shafts is recommended to prevent failures by corrosion fatigue. K Monel is preferred for applications where the design stress requires a high-strength shaft. Stainless shafts are more commercial and are frequently used, particularly for designs where the shaft is "covered," that is, effectively shielded from the liquid by the rotor parts of the pump. In these applications AISI Types 303, 304 and 316 may be used. Type 303 has the manufacturing advantage of being free-machining. Of the three, Type 304 is the least expensive raw material, and Type 316 is preferred for its superior resistance to pitting in sea and brackish waters.

Cutless rubber bearings usually are preferred for the vertical pumps. These bearings tend to promote concentration-cell attack of stainless steel, usually of the type associated with differential aeration. This is particularly true during periods when the pump is idle. For this reason, stainless shafts should be protected with a Monel sleeve when the circulating water is an effective electrolyte as in the case of sea water or harbor waters.

It should be noted also that pumps of this type are sometimes susceptible to cavitation. When this occurs, the suction bell is usually attacked in the area adjacent to the impeller. Figure 1 shows a portion of a cast iron

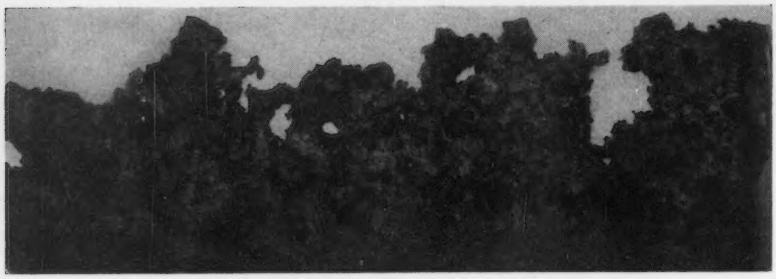

**Figure 1—Inside view, same specimen as in Figure 2.**

**Figure 2—Outside view, same specimen as in Figure 1.**

suction bell which had parted by cavitation in relatively non-corrosive, fresh-water service. The inside surface of the area immediately adjacent to the impeller is shown. It is apparent that no metal wastage has occurred near the bottom of the piece which was exposed to the same water. Figure 2 shows the absence of attack on the outside surface of the same piece, even though the outside was exposed to the same water handled by the pump.

The common commercial materials (iron, steel, tin, bronze and Ni-Resist) do not have sufficient resistance to cavitation to warrant their use in such cases. For this reason, the use of stainless steel suction bells or liners is recommended. A liner is usually more practical in the larger pumps. The stainless steel may be either AISI Type 309 or 316, as previously recommended for impellers.

### Conclusion

Corrosion-erosion in feed pumps has been substantially eliminated by changing to resistant materials, particularly steels containing 5% or more of chromium. Much progress has also been made in the pump materials for other central-station applications. Present materials have extended the periods between overhauls considerably. This represents a significant operating economy.

## ERRATUM

**Corrosion of Steel in Dilute Solutions of Sodium Salts of Weak Acids.** *Corrosion*, Vol. 9, No. 12, pages 467-477 (1953) Dec.

Page 469—For the cutlines under existing Figure 8 substitute the following:

**Figure 7—Panel exposed to 0.02N $Na_2CO_3$ + 100 ppm KCl for 3 months; appearance after removal of corrosion products (approx. X 2.5).**

For the cutlines under existing Figure 9 substitute the following:

**Figure 8—Panel exposed to 0.02N $Na_2CO_3$ + 100 ppm KCl for 6 months; appearance before removal of corrosion products (approx. X 2.5).**

For the cutlines under existing Figure 7 substitute the following.

**Figure 9—Panel exposed to 0.02N $Na_2CO_3$ + 100 ppm KCl for 6 months; appearance after removal of corrosion products (approx. X 2.5)**

in effect transposing cutlines so they are arranged in sequence left to right: Figure 7, Figure 8, Figure 9.

# Corrosion Testing by Measurement of Local Cell Potentials *

By J. K. RICE

WHENEVER a metal undergoes corrosion in a dilute solution of an electrolyte, the action that takes place is that of countless local cells on the surface of the metal. The total amount of metal that goes into solution per unit area is the sum of the amount going into solution from each of the local cells in the unit area. The local cell action rates differ and are a complex function of the local cell potentials as well as the solution characteristics. The local cell potentials in turn are a function of chemical composition, crystal structure and stress at each point on the surface of the metal.

The measurement of these local cell potentials and the ohmic potentials resulting from the local cell currents has, until lately, only been practical or possible in a very few special cases. The problems that made earlier attempts at these measurements so difficult have been largely overcome by the use of a rotating electrode, composed of the metal under test, in conjunction with a stationary probe electrode. Several papers describing briefly the apparatus and techniques have been presented by McAndrews, Colner and Francis[1,2] and by the author.[3,4]

## Principle

The principle of the method is the rapid movement of the specimen surface along a recurrent path past a stationary probe electrode. The probe in effect acts as a slide contact along the resistance of path A—A in the electrical analogy shown in Figure 1. Since the potentials along the path differ from point to point the relative motion of probe and specimen surface produces a small AC potential impressed upon the large DC potential of the cell, specimen-reference electrode. By making the path of the probe recurrent, in this case along a circumference of the specimen, the pattern of potentials is made recurrent. The recurrent potentials can then be studied using an oscilloscope. The result is a stationary trace on the face of the cathode ray tube. The ordinates of the trace (y-axis) are the potentials of the cell, specimen-reference electrode, along the path of the probe (x-axis). The apparatus used to make these measurements is shown in Figures 2, 3 and 4.

## Apparatus

The test specimen is a cylindrical rod 0.25-inch in diameter and 3 inches in length. It is held in a mandrel which is rotated at a constant speed of 1100 rpm. The end and the middle of each specimen is coated with a polyethylene dope to prevent end and water line effects. The specimen is immersed in the desired solution. Approximately one inch in length of the surface is exposed to the solution, the remainder being masked as above. The probe electrode is constructed by drawing out to a capillary 8 mm OD glass tubing. The capillary portion is filled with a KC1 agar solution. The undrawn portion is filled with saturated KC1 and a mercury-calomel half cell. The entire probe is held and positioned by a micrometer screw device that allows the probe to be precisely moved both to and from the surface of the specimen and also parallel to the longitudinal axis of the specimen. Thus the entire surface of the specimen may be scanned by the probe at any desired distance from the surface.

The solution chamber is made of glass and holds

★ A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

JAMES K. RICE—Vice president and director of service of Cyrus Wm. Rice and Company, Pittsburgh, started work with his employers in 1947, first in research and development and later in field engineering. He has a master's degree in chemical engineering from Carnegie Institute of Technology. He was an engineering officer in the Marine Corps during the last war. He is a member of Sigma Xi, Tau Beta Pi, AIChE, and ASTM.

## Abstract

The method of studying corrosion rates by measuring the local cell potential using a rotating electrode and stationary micro-probe reference electrode is briefly reviewed. The results are presented of applying the method to the study of the effect of different variables on the corrosion inhibition properties of hexametaphosphate on steel in aerated water systems.

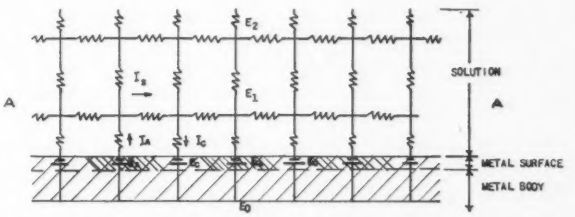


Figure 1—Analogous electrical circuit of metal corroding in electrolyte.

| | |
|---|---|
| $E_A$ | Potential of local anode at surface |
| $E_C$ | Potential of local cathode at surface |
| $E_O$ | Potential of main body of metal |
| $E_1$, $E_2$ Etc. | Potentials in solution |
| $I_A$ | Current from anode |
| $I_C$ | Current to cathode |
| $I_S$ | Current between cathode and anode areas |

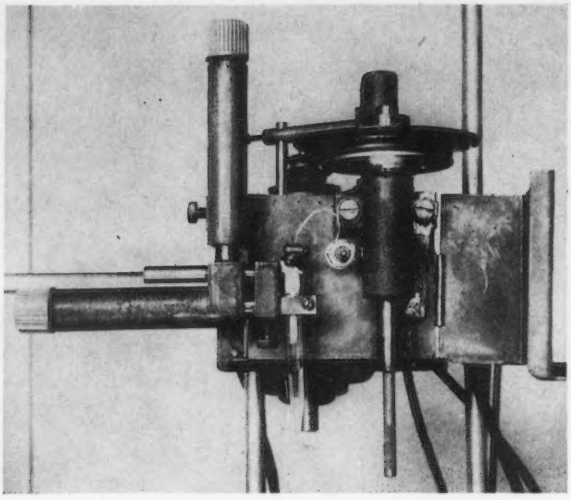

Figure 2—Rotating electrode, shield removed.

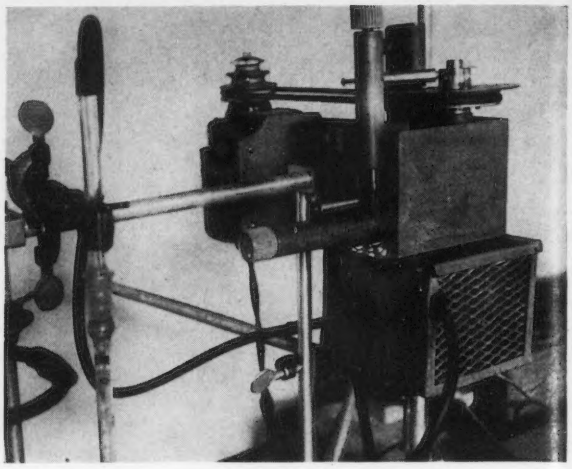

Figure 3—Rotating electrode, shielding in place.

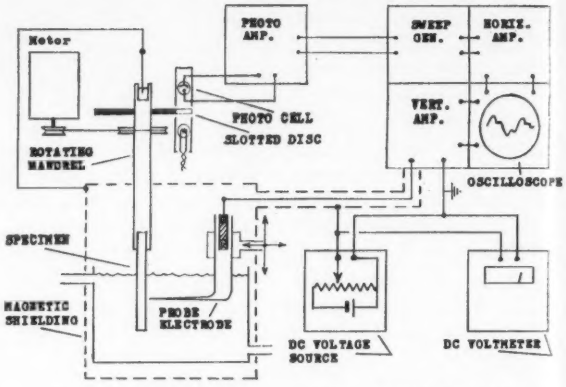


Figure 4—Schematic diagram, rotating electrode assembly.

approximately 500 ml. It has provision for inflow at the bottom and overflow near the top.

The specimen, the probe and the solution chamber are all enclosed by magnetic shielding to prevent induced emf's in the measuring circuit.

The probe electrode is connected to the input of a DC amplifier. The input lead is coaxial shielded wire with shielded connectors. The specimen is firmly held in the rotating mandrel to assure good electrical contact. The rotating mandrel is connected to the magnetic shielding by a mercury pool contact. A shielded variable DC voltage source is connected between the magnetic shielding and the grounded input terminal of the DC amplifier. This DC voltage source is used to cancel out the DC voltage of the cell specimen-probe and thus allow maximum amplification of the relatively small AC component without distortion. It has the advantage over the DC blocking capacitor formerly used in that the exact values of the DC potential may be measured simultaneously with the measurement of the AC component.

The output of the DC amplifier is connected to the vertical deflection plates of the cathode ray tube. The horizontal deflection plates of this tube are coupled to a linear sweep generator, the frequency of which is synchronized with the rotation of the specimen. This synchronization is accomplished by a photoelectric device and suitable amplifier. A light source and a gas filled miniature photo tube are mounted near the rotating mandrel in such a way that a slot in a disc attached to the mandrel allows light to strike the phototube once each revolution of the disc, thus furnishing a timing pulse to the sweep generator.

It is very important to underscore the need for thorough magnetic shielding of all portions of the apparatus because of the high resistance of the electrical circuits and the high amplification factor required. Failure to properly shield results in a low signal-to-noise ratio, the noise taking the form of 60-cycle wave form imposed on the measured trace.

External to the rotating electrode assembly is the test solution system. The test solution is circulated continuously by a small pump from a reservoir to the solution chamber in the electrode assembly. The solution then overflows to an aerating column where it is contacted by a finely dispersed air stream. The solution then returns to the reservoir. The reservoir is agitated and maintained at a constant temperature. Obviously, any type of external system may be employed depending upon the environment under study.

It should be noted that whenever the specific conductance of the test solution is high, 100,000 mmhos or greater, it is necessary to shield the entire solution system as the solution will pick up induced emf's as will exposed wiring. The same holds true at specific conductance greater than 100 mmhos if a secondary reference electrode of high resistance is used in place of the rotating specimen and if the specimen is electrically isolated from the system.

## Technique of Measurement

The test specimens are prepared in a normal manner by degreasing, pickling, etc. The test solution and reference electrode are brought to thermal equi-

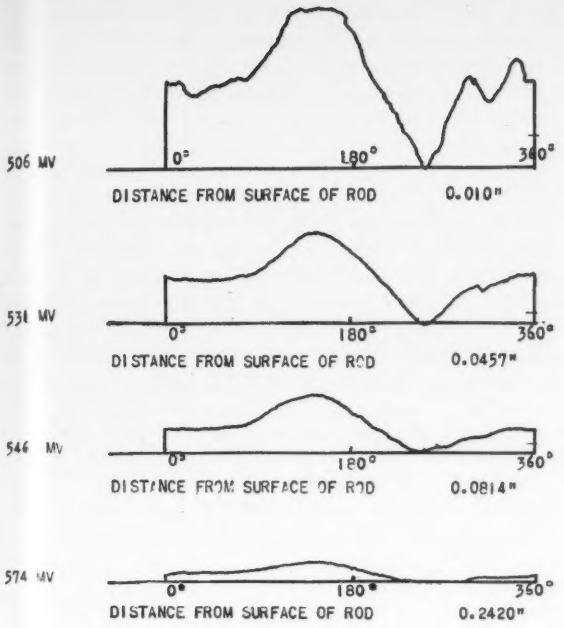


Figure 5

librium at the desired temperature. All electrical components are turned on for approximately one hour before any measurements are to be made in order to prevent subsequent drifting.

The prepared test specimen is mounted on the rotating mandrel immersed in the solution. The probe electrode is moved to whatever distance desired from the surface of the specimen. The distance employed for the inhibitor tests to be described was 0.010-inch. The recording of the initial trace is begun within one minute after the specimen is immersed.

The traces are recorded by drawing the trace on graph paper using an optical copying device.

The probe electrode is moved away from the surface to a distance of about 0.5-inch between each recording. It is necessary to do this to prevent prolonged disturbances of the flow next to the surface and hence to prevent disturbance of any of the normal reactions occurring at the surface.

The early tests with the rotating electrode were made by choosing a position along the longitudinal axis of the specimen to give a maximum amplitude of trace, then using the same position for all subsequent traces on that specimen. The inhibitor tests to be described were made by choosing a maximum amplitude of trace for each trace recorded.

### Interpretation of Traces

As noted previously the traces represent the potentials of the cell, specimen-reference electrode, along the path of the probe over the surface of the specimen. The potential differences recorded along any one circumference result both from the potential differences of the local anode and cathode areas and from the ohmic potentials due to local corrosion currents. As the corrosion currents are a complex function of both the local cell potentials and the resistance of the current path, the correlation of the recorded traces to local corrosion rates can only be on a relative basis. With the information available the limitations thus imposed are those of comparing traces at the same specific conductance and at the same distance from the surface.

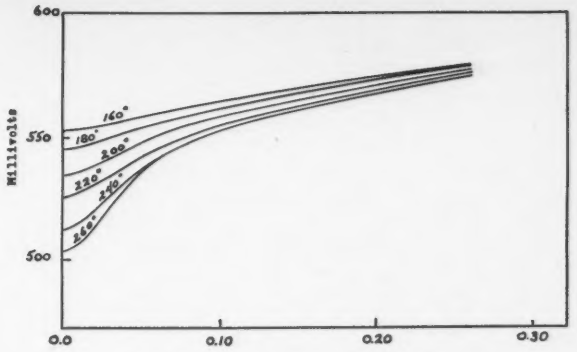


Figure 6—Potentials along selected radii.

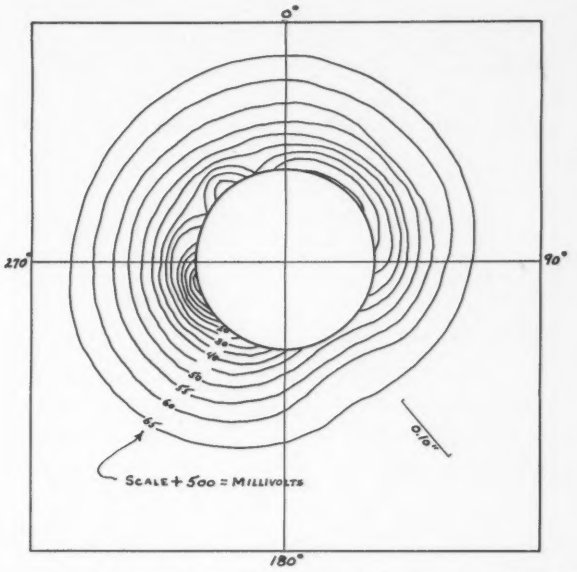


Figure 7—Equipotential plot. Temperature 46 degrees C, conductivity 265 mmhos, pH 6.2.

The parameter used to interpret the traces of the comparative tests later described was obtained by determining the area between the trace and an abscissa drawn through the point of minimum potential on the trace. This parameter is, in effect, the integral of the current vectors parallel to the surface and in the plane of the path of the probe perpendicular to the axis of rotation.

It was early noted that the local anode and cathode areas were constantly changing with first one and then another becoming dominant. This made it necessary to locate the probe for each trace recorded so that it was over a circumference producing a maximum area of trace. The area units reported are arbitrarily in square millimeters.

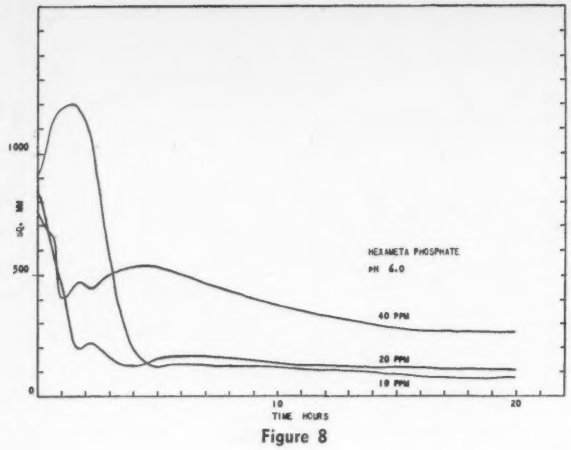


Figure 8

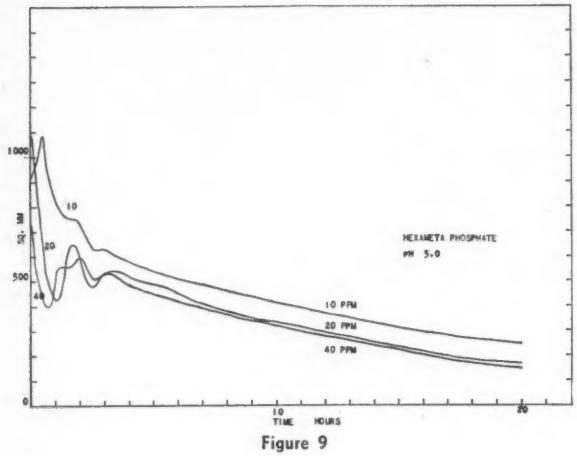


Figure 9

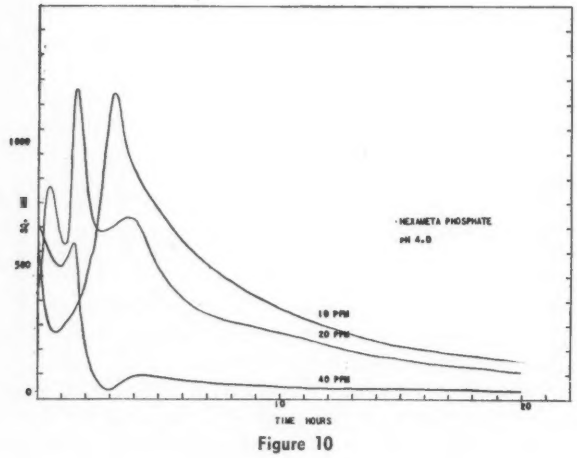


Figure 10

## Discussion of Results

Figure 5 shows a number of typical trace patterns obtained at different distances from the surface of the same specimen at the same location along the longitudinal axis of the specimen. These traces were recorded within a 10 minute period at a time when the local anode-cathode rates were fairly constant. The potential of the abscissa through the lowest point on each trace is indicated. Since distance along the X-axis from the start to the finish of each trace represents one complete circumference, the X-axis is divided 0-360 degrees. Figure 6 is a plot of the potentials along selected radii in the plane of rotation. These potentials were obtained from traces shown in Figure 5. It is well to note that the slope of each curve is positive, which indicates that while there is current flow between the anode and cathode areas covered by this trace, there is considerable current flow to this entire area from predominantly anodic areas elsewhere on the surface of the specimen.

Figure 7 is a plot of points of equal potential in the plane of rotation. It was made from the radial potentials of Figure 6. Visual inspection of the test specimens has always shown that intensely cathodic areas such as that at 260 degrees in Figure 7 are free of deposit. If the recording of traces is performed rapidly enough, it is possible to draw a potential contour map of an area of the specimen at any desired distance from the surface.

Figures 8 through 10 are graphs of trace areas vs time. The traces were made at a constant distance from the surface and along circumferences producing maximum areas of trace. They demonstrate the effect of various inhibitor concentrations at different pH values.

Trace areas of less than 200 mm² correspond to very low corrosion rates as evidenced by visual inspection of the specimen surface. Trace areas of 1500 mm² are obtained on specimens in uninhibited solutions and correspond to high corrosion rates.

The trace area-time curves are generally reproducible to within 50 mm² after the first 3 to 4 hours. The precision seems to vary considerably with the choice of inhibitor. It is now suspected that the relatively poor precision results from the failure to take into account the difference between the mean potential of the cells along the circumference recorded and the potential of the specimen as a whole; i.e. the circumference may be over an area highly cathodic (or anodic) with respect to the rest of the surface. It has been observed from the traces that the lesser anodic areas are rendered passive by an anodic inhibitor before the strongly anodic areas. Therefore, trace areas obtained over portions of the surface predominantly cathodic with respect to the rest of the surface would be expected to reduce more rapidly with time under the effect of an anodic inhibitor than trace areas from predominantly anodic portions of the surface. If the foregoing is correct it imposes another restriction on the comparison of tests.

## Summary

Use of the method to date has confirmed the existence of anodes in predominantly cathode areas and vice versa. It has confirmed the continued change in potential from anode to cathode and vice versa of the local cells. It has indicated that the variation in the potential of the entire specimen results in part from the changes in the ratio of the number of local anodes to cathodes. It has indicated the existence of very

high resistance films on the surface and the possibility of studying the magnitude of these resistances by studying the effect on potentials of changes in the specific conductance of the solution.

The rotating electrode method as described is, therefore, a very practical means of studying the local cell action on the surface of a specimen in a dilute electrolyte. At this present stage of development it is not possible to relate the information obtained directly to weight loss or similar figure without an excessive amount of computation. Within the limitations discussed the results are comparable and furnish far more information about the action of inhibitors, the effect of various solution variables and surface conditions that is possible by other means. One of the most serious limitations of the method, however, is its inability to measure corrosion processes under zero flow conditions.

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2. J. B. McAndrew, W. H. Colner and H. I. Francis. Rotogenerative Detection of Corrosive Currents. National Advisory Committee for Aeronautics, Technical Note 2523, November, 1951.
3. J. K. Rice. A Review of Testing Techniques in Cooling Towers. Paper presented at 13th Annual Water Conference, Engineers Society of Western Penn., October 21, 1952.
4. J. K. Rice. The Rotating Electrode as a Method of Measurement of Local Cell Action Potentials in Corrosion Testing. Paper presented to the Houston Section, NACE, Houston, December 9, 1952.

## DISCUSSION

**Discussion by Robert S. Y. Yoseph, Chief, Sanitary Engineering, Strategic Air Command, Offutt Air Force Base, Omaha, Neb.:**

The problem of the effects of stray currents on the measurements by the rotating electrode system were brought out very nicely by the author. This problem was encountered on a research project conducted at the Hydrodynamics Laboratory at MIT where I was working on the development of a unit for the measurement of dissolved oxygen in aeration tanks based on the dropping mercury and rotating platinum electrodes (MIT Tech Report 3, Public Health Project No. R. G. 863, 1951, titled "Continuous Measurements of Oxygen Concentration in Water During Aeration Processes," by A. T. Ippen, R. S. Y. Yoseph and B. N. Posthill). After the unit was developed and experimental aeration tanks constructed, erratic readings were obtained with no apparent reason. This was puzzling inasmuch as satisfactory measurements were carried out for the calibration of the recorder on batch samples. The problem of stray currents was investigated and it was determined that by completely shielding the experimental apparatus as well as the recording unit, satisfactory measurements could be obtained with no difficulty. Thus, it became necessary to mount the aeration unit on rubber mountings and electrically isolate other parts of the apparatus. Voltage stabilizers were used on all electric outlets. In my opinion, the commercial application of the oxygen recorders based on polarography is contingent upon the elimination of the effects of stray currents on the electrode units. This may prove to be a formidable task on certain aeration processes where measurement of dissolved oxygen is of prime importance.

**Discussion by Horace A. Cataldi, Chicago, Ill.:**

The author has perhaps overemphasized the difficulties in electrical shielding, perhaps to the point of discouraging others from attempting similar measurements. We have used the method to study intergranular and welding effects. The electrolyt is contained in a glass beaker. The only precautions necessary have been to shield the signal lead and ground the various pieces of apparatus. I wonder if the author can suggest what the differences in the two systems might be. Perhaps we are simply fortunate to be in a low "stray" area.

**Reply by James K. Rice:**

The difficulties with induced emf's are greatly reduced as the conductivity of the electrolyte is increased. Solution conductivities of the order of several micro-mhos require very extensive shielding of the leads and the solution container. Solution conductivities of several thousand micro-mhos require good shielding of the leads and only minor shielding of the solution container.

# Laboratory Measurement of the Corrosion of Ferrous Metals in Soils*

By W. J. SCHWERDTFEGER*


## Abstract

A method is described for setting up soil-corrosion cells using a soil-wetting procedure that gives reproducible results. By measuring the weight losses on cell electrodes made of steel and of cast iron after exposure to various soils for six months, it was possible to compare the effects of corrosion on the two materials. It was also found that the electrode weight losses correlated with the weight losses and maximum pitting on wrought ferrous specimens exposed for 10 years at the field test sites. Because the laboratory soils covered the range of corrosivity peculiar to soils, it was possible to derive empirical equations for predicting weight loss and pitting at the end of 10 years for presumably any soil. It is also shown how reasonable adjustments can be made for areas other than that of the field specimens and for exposure periods other than 10 years.


## 1. Introduction

A REVIEW of the field corrosion data obtained by the National Bureau of Standards invariably results in the conclusion that no single soil property is a good measure of its corrosivity toward iron or steel. Because the normal corrosion of iron and steel underground is an electrolytic phenomenon, several accelerated laboratory and field tests based on electrical measurements have been devised that purport to measure the corrosivity of soils. Ewing[1] has pointed out that the majority of such tests in effect really measures soil resistivity. Whereas measurements of soil resistivity made along a pipe line might correlate very well with the evidence of corrosion on the surface of that particular pipe, it is also true that there is no general correlation between the corrosion of ferrous metal exposed to different soils and the soil resistivity.

Denison[2,3] described a laboratory corrosion cell in which an electromotive force was developed by differential-aeration between two steel electrodes separated by soil as the electrolyte. The maximum current measured between the electrodes over a 2-week period was used as an index of soil corrosivity. A fair correlation was obtained between laboratory and field data except for the soils of relatively high resistivity. In such soils, because of local action, the anode weight losses were more significant than the cell currents as an index of soil corrosivity.

Logan, Ewing, and Denison[4] have shown by field exposure tests that the corrosion rate of iron and steel in soils varies from an almost constant rate with time in some soils to virtual cessation within a few years in other soils. Such information is of great value to those concerned with underground construction. The time required to conduct such tests in the field, however, is long, and the required information cannot be obtained, in many cases, when it is most needed. A suitable laboratory test using the soil in question and operating over a sufficiently long period to reflect any change in the rate of corrosion of iron and steel with time is most desirable. The data from such a test should be correlated with known field-exposure data so that the results can be correctly interpreted. The extensive field exposure tests of the National Bureau of Standards provide a considerable volume of data that can be used for this purpose.

The corrosion cell used for this investigation is a modification of the cell described by Denison. It lends itself to better reproducibility than the original cell and will remain operative for a longer period of time.

Although electrical measurements can be made that account for all weight loss of steel exposed to soils,[5] weight loss is used as the corrosion index, because electrical measurements would have to be made frequently to account for the change in corrosion rate with time.

## 2. Experimental Methods

### *2.1. Description of the Corrosion Cell*

The corrosion cell and all of its components are shown in Figure 1. The cell consists essentially of a

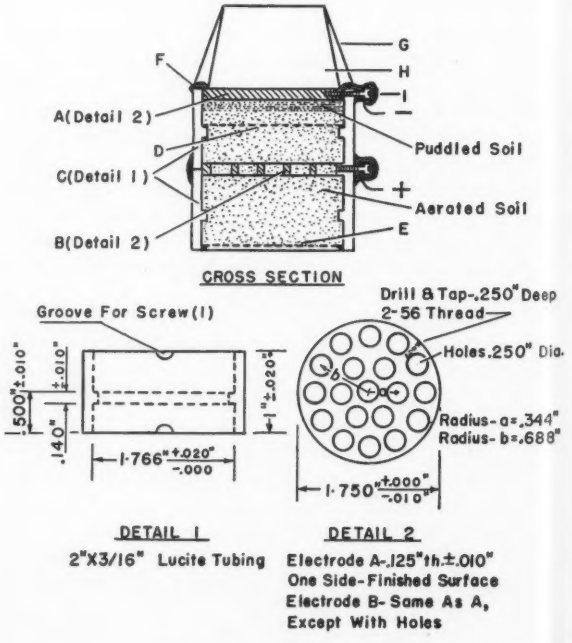



Figure 1—Soil-Corrosion Cell.

★ Reprinted from the Journal of Research, National Bureau of Standards, 50, No. 6, 329-336 (1953) June.

* National Bureau of Standards, U. S. Dept. of Commerce, Washington, D. C.

weighed iron or steel anode, A, and a weighed perforated cathode, B, made of the same material, both provided with electrical connections and separated by soil of a definite moisture content. The soil is contained in two Lucite cylinders, C. Other parts of the cell that serve to hold the soil in place and thus insure good contact with the electrodes are two stainless-steel screens, D and E, the rubber stopper, H, and the rubber band, G. The components are joined with asphalt, F, which also serves as a sealer. Aeration of the cathode is accomplished by adjusting the moisture content of the soil, and access of air to the anode is restricted by mechanically working the layer of soil in contact with it, which results in a difference of potential between the electrodes. Details concerning the preparation of the cell are given in the appendix.

### 2.2. *Use of the Corrosion Cell*

The behavior of the corrosion cells in reflecting the effect of time on corrosion of iron or steel is illustrated by Figure 2. The cell currents were measured with a zero-resistance milliammeter without permitting the cells to be on open circuit. The currents for each soil are the average values for four cells. It will be noted from the table in the figure that the electrode weight losses indicate the actual order of corrosivity of the soils, whereas the average cell currents in soils 62 and 26 are in reverse order because of the soil resistivities. However, based on field data of Denison and Romanoff[6] the curves do reflect the effect of time on the rate of corrosion of ferrous materials in the three soils. The field data reveal a fairly constant rate of corrosion of wrought materials exposed to soils 64 and 62 over a period of 14 years and a stifling effect in well-aerated soils similar to soil 26. It will be noted, Figure 2, that in soil 26 the cell current gradually decreases, whereas in soils 64 and 62 after the initial decrease the currents are relatively steady.

As a result of this and other experiments, six months was chosen as the minimum time required for measuring soil corrosion. Although the laboratory results are based on the weight lost by the cell electrodes, the cell current serves to reveal the quality of a cell. If a diverse cell, indicated by incorrect polarity or relatively low current, exists in a particular soil group 2 weeks after assembly time, that cell should be replaced. Six months after assembly the corrosion cells are taken apart and the electrodes cleaned by methods[7] already described. The average combined loss of metal on the anodes and cathodes for the four cells is used as the corrosion index.

## 3. Comparison of the Corrosion of Steel and Cast Iron

### 3.1. *Weight Loss in the Laboratory Tests*

Although the laboratory corrosion test was planned primarily to show the relative effects of various soils on ferrous materials, to be shown later, the sensitivity of the test can be better evaluated if it is possible to detect differences in the corrodibility of commonly used plain ferrous materials when exposed to a given soil environment. To that end, corrosion cells were assembled with both steel and cast-iron electrodes, using several soil samples collected at the test sites of the National Bureau of Standards and known to cover the range of corrosivity. The location of the test sites and some of the soil properties are given in Table 1, along with other soils to be discussed later.

The results of the laboratory tests are given in Table 2. In all of the soils, with the exception of soil 5, the steel electrodes were more resistant to corrosion

**TABLE 1—Properties of the Soils**

| Soil No.[a] | Soil Type | Soil Location of site | pH | Resistivity at 60°F | Aeration[b] |
|---|---|---|---|---|---|
| | | | | *Ohm-cm* | |
| 4 | Chester loam | Jenkintown, Pa. | 5.6 | 6,670 | G |
| 5 | Dublin clay adobe | Oakland, Calif. | 7.0 | 1,346 | P |
| 8 | Fargo clay loam | Fargo, N. Dak. | 7.6 | 350 | P |
| 15 | Houston black clay | San Antonio, Tex. | 7.5 | 489 | P |
| 25 | Miami clay loam | Milwaukee, Wis. | 7.2 | 1,780 | F |
| 26 | Miami silt loam | Springfield, Ohio | 7.3 | 2,980 | G |
| 32 | Ontario loam | Rochester, N.Y. | 7.3 | 5,700 | G |
| 41 | Summit silt loam | Kansas City, Mo. | 5.5 | 1,320 | F |
| 43 | Tidal marsh | Elizabeth, N.J. | 3.1 | 60 | VP |
| 55 | Hagerstown loam | Lock Raven, Md. | 5.8 | 5,213 | G |
| 56 | Lake Charles clay | El Vista, Tex. | 7.1 | 406 | VP |
| 61 | Sharkey clay | New Orleans, La. | 5.9 | 943 | P |
| 62 | Susquehanna clay | Meridian, Miss. | 4.1 | 6,922 | F |
| 64 | Docas clay | Cholame, Calif. | 8.3 | 62 | F |
| 65 | Chino silt loam | Wilmington, Calif. | 7.2 | 148 | F |

[a] Soil number also refers to site number as specified in the NBS soil-corrosion studies.
[b] Aeration of soils: G, good; F, fair; P, poor; VP, very poor.

**TABLE 2—Comparison of the Corrodibility of Steel and Cast Iron in the Laboratory**

| | LOSS IN WEIGHT OF CELL ELECTRODES IN 6 MONTHS[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | STEEL[b] | | | CAST IRON[c] | | | | | | |
| SOIL | Number of Cells | Mean, $w_1$ | Standard Error, $\sigma_{w_1}$ | Number of Cells | Mean, $w_2$ | Standard Error, $\sigma_{w_2}$ | Difference Between the Means, $w_1 - w_2$ | Standard[d] Error of the Difference, $\sigma_{(w_1-w_2)}$ | Value of $t$[e] | Probability of Difference Due to Chance |
| | | *oz/ft²* | *oz/ft²* | | *oz/ft²* | *oz/ft²* | *oz/ft²* | *oz/ft²* | | *Percent* |
| 4 | 4 | 0.61 | 0.065 | 4 | 0.85 | 0.028 | −0.24 | 0.071 | 3.4 | <2 |
| 5 | 8 | 1.97 | .14 | 7 | 1.82 | .25 | + .15 | .29 | 0.5 | 60 |
| 8 | 4 | 0.89 | .045 | 6 | 1.46 | .13 | − .57 | .14 | 4.1 | <1 |
| 25 | 4 | .20 | .021 | 4 | 0.46 | .056 | − .26 | .060 | 4.3 | <1 |
| 26 | 4 | .56 | .049 | 4 | .65 | .037 | − .09 | .061 | 1.5 | 18 |
| 32 | 4 | .37 | .040 | 4 | .53 | .032 | − .16 | .051 | 3.1 | <2 |
| 43 | 4 | 1.36 | .18 | 4 | 3.40 | .16 | −2.04 | .24 | 8.5 | <1 |
| 56 | 4 | 2.17 | .072 | 4 | 2.33 | .11 | −0.16 | .13 | 1.2 | 30 |
| 62 | 4 | 1.05 | .098 | 4 | 1.79 | .081 | − .74 | .13 | 5.7 | <1 |
| 64 | 4 | 2.53 | .20 | 4 | 3.84 | .20 | −1.31 | .028 | 4.7 | <1 |

[a] Combined loss in weight of the anode and cathode. Area exposed, anode =2.4 in.² (15.5 cm²), cathode =3.3 in² (21.3 cm²).
[b] Composition of steel, in percent: 0.23 C, 0.58 Mn, 0.008 P, 0.025 S, 0.095 Si, 0.077 Cu.
[c] Composition of cast iron in percent: 3.42 C (total), 2.59 C (free), 0.83 C (combined), 1.53 Si, 0.72 P, 0.68 Mn, 0.082 S, 0.05 As.
[d] $\sigma_{(w_1-w_2)} = \sqrt{(\sigma_{w_1})^2+(\sigma_{w_2})^2}$ (See text)
[e] $t = \dfrac{w_1-w_2}{\sigma_{(w_1-w_2)}}$ (See text)

than were the cast-iron electrodes. The significance of the difference indicated in the table is based on the standard *t*-test.[8] It will be noted that the better corrosion resistance exhibited by cast iron over steel in soil 5 may be attributed to chance.

### *3.2. Comparison of Laboratory and Field Data*

A comparison of laboratory and field data pertaining to the corrosion of steel and cast iron is reasonable if the laboratory soil samples are representative of the soil in the trenches from which the field specimens were removed. The field data are shown in Table 3. For all of the soils, except 56, 62, and 64, the data are based on weight losses reported by Logan[7] occurring on pipe specimens of Bessemer steel and on cast-iron pipe consisting of two de Lavaud specimens, one Northern pit cast iron, and one Southern pit cast-iron specimen. Data in Table 3 pertaining to soils 56, 62 and 64, were reported by Denison and Romanoff.[6]

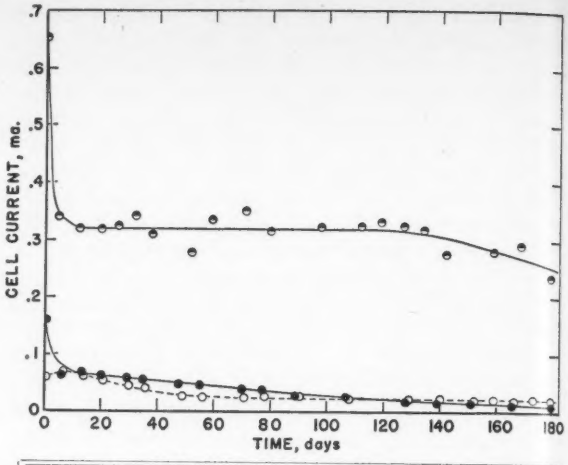
In all soils (Table 3) except soil 62, the steel specimens lost less weight than did the cast-iron specimens. The statistical significance of the difference in weight loss, as in the case of the laboratory comparison, is based on the *t*-test and, except in soils 62, 43, and 64, shows substantially the same results. For soils 43 and 62 the laboratory and field comparisons of the corrosion of steel and cast iron are inconclusive; and in the case of soil 64, the field data are so variable that any significant difference between the steel and cast iron is obscured. In soil 64, the standard errors applying to the laboratory data (Table 2) are relatively small. Therefore, the laboratory results in soil 64 are to be taken as being the more significant.

The preponderance of negative values in column 8 of Table 3 is not to be considered as indicating the relative behavior of the materials in soils generally.

## 4. Measurement of Soil Corrosivity

### *4.1. Correlation Between Laboratory and Field Weight Losses*

In order to further evaluate the laboratory corrosion test as a measure of the relative corrosiveness of soils toward commonly used ferrous materials, the mean weight losses of steel electrodes after exposure for six months to the soils shown in Table 1 were correlated with the average weight losses of other specimens exposed to the test sites for 10 years. The specimens at each test site totaled eight in number




| Symbol | Soil | Resistivity | Cell current [1] | Weight loss of cell electrodes [2] | Corrosivity of soil [3] |
|---|---|---|---|---|---|
| | | *Ohm-cm* | *ma* | | |
| ◓ | 64 | 62 | 0.280 | 2.53 | Most. |
| ○ | 62 | 6922 | .030 | 1.05 | Intermediate. |
| ● | 26 | 2980 | .035 | 0.56 | Least. |

[1] Calculated from the area under a line through the points.
[2] Combined weight loss of the anode and cathode exposed for 180 days, in ounces per square foot.
[3] Order shown by the field-exposure tests.

**Figure 2—Effect of exposure time on the corrosion of steel in soils.**

and consisted of two of each of the following materials: Low-carbon steel, hand-puddled wrought iron, mechanically puddled wrought iron and open-hearth iron.

In developing the laboratory test, the National Bureau of Standards was fortunate in having the cooperation of the Waterways Experiment Station, Corps of Engineers, U. S. Army. That laboratory followed the same procedure in measuring the corrosiveness of soils as described in Section 2. The soil samples tested by the Waterways Experiment Station included nine of the 10 soils studied by the National Bureau of Standards and in addition 5 soils removed from other National Bureau of Standards test sites. The nine soils tested by both laboratories were not taken from the same samples but were removed from different parts of the trench at the nine sites. Both laboratories used steel cell electrodes of the same chemical composition and dimensions. The composition and dimensions are given in Table 2. The data

**TABLE 3—Comparison of Steel and Cast Iron After 12 Years of Field Exposure**
Loss in weight of field specmiens

| SOIL | STEEL | | | CAST IRON | | | Difference Between the Means, $X_1-X_2$ | Standard Error of the Difference, $\sigma_{X_1-X_2}$ | Value of $t$ | Probability of Difference Due to Chance |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Specimens | Mean $X_1$ | Standard Error $\sigma_{X_1}$ | Number of Specimens | Mean $X_2$ | Standard Error $\sigma_{X_2}$ | | | | |
| | | *oz/ft²* | *oz/ft²* | | *oz/ft²* | *oz/ft²* | *oz/ft²* | *oz/ft²* | | *Percent* |
| 4 | 6 | 6.6 | 0.19 | 4 | 15.1 | 2.7 | —8.5 | 2.7 | 3.1 | <2 |
| 5 | 6 | 6.6 | .44 | 4 | 10.5 | 3.3 | —3.9 | 3.4 | 1.2 | 28 |
| 8 | 6 | 7.5 | .41 | 4 | 21.2 | 3.3 | —13.7 | 3.4 | 4.0 | <1 |
| 25 | 6 | 3.2 | .14 | 4 | 3.5 | .06 | —.3 | .14 | 2.1 | 5 |
| 26 | 6 | 3.6 | .14 | 4 | 4.1 | .11 | —.5 | .18 | 2.8 | <2 |
| 32 | 6 | 3.7 | .25 | 4 | 4.8 | .59 | —1.1 | .64 | 1.7 | 14 |
| 43 | 6 | 16.8 | 1.9 | 4 | 17.7 | 1.8 | —.9 | 2.6 | .3 | 70 |
| 56[a] | 8 | 30.5 | 2.3 | 8 | 40.5 | 6.8 | —10.0 | 7.2 | 1.4 | 18 |
| 62[a] | 8 | 6.9 | 1.0 | 8 | 5.9 | 1.1 | +1.0 | 1.5 | .6 | 55 |
| 64[a] | 8 | 50.9 | 9.0 | 8 | 58.0 | 5.8 | —7.1 | 10.7 | .7 | 50 |

[a] Exposure 14 years.

obtained by both laboratories and the National Bureau of Standards field data are tabulated in Table 4. Correlation between the laboratory and field weight losses is based on the text of Croxton and Cowden.[8] The coefficient of correlation between the National Bureau of Standards laboratory and field data is 0.84. The coefficient between the Waterways Experiment Station data and the National Bureau of Standards field data is 0.6, but by eliminating soil 64 the coefficient becomes 0.87.

Because the soils listed in Table 4 cover the range of corrosivity of soils peculiar to the United States, the data of both laboratories are used to set up the equation of best fit,[9] presumably a linear relationship, between the laboratory and field weight losses, which it is again presumed will be applicable to any soil, whatever its degree of corrosivity. The standard errors associated with the weight losses were about the same for both laboratories except for the Waterways Experiment Station data pertaining to soil 64, in which the standard error was considerably larger than for all other data. As the inclusion of soil 64 adversely affected the correlation between the Waterways Experiment Station data and the field data, the Waterways Experiment Station data pertaining to this soil are omitted. Thus, by averaging the weight losses in each of eight soils (4, 5, 25, 26, 32, 43, 56, 62, Table 4) tested by the two laboratories and using the individual laboratory weight losses in the seven other soils (8, 15, 41, 55, 61, 64, 65, Table 4), the correlation betwen the combined laboratory weight losses and the National Bureau of Standards weight losses in the field results in a correlation coefficient of 0.83. All correlation coefficients were corrected for size of sample. Based on the correlation coefficient of 0.83, the equation relating the laboratory and field data is

$$W_{10} = 8.45w - 1.1, \qquad (1$$

where $W_{10}$ is the anticipated weight loss on the commonly used ferrous specimens after 10 years of field exposure, expressed in ounces per square foot. $w$ is the mean combined weight loss in six months of the anode and cathode of corrosion cells, expressed in ounces per square foot. The standard error of estimate associated with this relationship is ±4.1 oz/ft².

The calculated weight losses on the National Bureau of Standards specimens based on eq (1 are tabulated in Table 4, along with the actual weight losses. Relatively large discrepancies appear between the actual and calculated values in soils 5, 41 and 61. In the case of soils 41 and 61, the discrepancies might be attributed to the laboratory test. Soil 5, however, is fine in texture, very dense, and poorly aerated, and also possesses other characteristics which Denison and Ewing[10] associated with very corrosive soils. Also, a reference to some early information published by Logan, Ewing, and Yeomans[11] revealed that iron pipe removed from soil five was severely corroded. Probably the conditions within the trench from which the field specimens were removed were not typical of the general soil structure. Therefore, for soil five at least, the laboratory data are considered a better index of the potential soil corrosivity than are the field data.

**TABLE 4—Correlation Between Combined Laboratory and National Bureau of Standards Field Data**

| SOIL | Weight Loss of Steel Electrodes After 6 Mos. of Laboratory Exposure | | | Weight Loss of Wrought Ferrous Specimen After 10 Years of Field Exposure | | Maximum Pit Depth of Wrought Ferrous Specimens After 10 Years of Field Exposure | |
|---|---|---|---|---|---|---|---|
| | National Bureau of Standards | Waterways Exp. tion | Average $w$ | Actual | Calculated $W_{10}$ | Actual | Calculated $P_{10}$ |
| | oz/ft² | oz/ft² | oz/ft² | oz/ft² | oz/ft² | Mils | Mils |
| 4 | 0.61 | 0.91 | 0.76 | 6.4 | 5.3 | 75 | 63 |
| 5 | 1.97 | 1.41 | 1.69 | 6.4 | [a]13.2 | 50 | [a]104 |
| 8 | .89 | .... | .89 | 5.5 | 6.4 | 79 | 69 |
| 15 | .... | 1.27 | 1.27 | 7.0 | 9.7 | 63 | 86 |
| 25 | .20 | .86 | .53 | 2.6 | 3.4 | 49 | 53 |
| 26 | .56 | .48 | .52 | 2.5 | 3.3 | 59 | 53 |
| 32 | .37 | .56 | .46 | 3.1 | 2.8 | 55 | 50 |
| 41 | .... | .32 | .32 | 6.1 | 1.6 | 64 | 44 |
| 43 | 1.36 | 2.18 | 1.77 | 12.6 | 13.9 | 112 | 108 |
| 55 | .... | .43 | .43 | 3.2 | 2.5 | 75 | 49 |
| 56 | 2.17 | 3.23 | 2.70 | 21.2 | 21.7 | 132 | 148 |
| 61 | .... | 1.69 | 1.69 | 7.1 | 13.2 | 72 | 104 |
| 62 | 1.05 | .91 | .98 | 6.2 | 7.2 | 78 | 73 |
| 64 | 2.53 | 1.49 | [a]2.53 | 30.0 | 20.3 | 145 | 141 |
| 65 | .... | 1.03 | 1.03 | 11.9 | 7.6 | 100 | 75 |

[a] See text, section 4.

### 4.2. *Correlation Between Weight Loss and Maximum Penetration*

The value of a laboratory corrosion test would be immeasurably increased if it could be used to predict the maximum depth of pitting under normal field exposure. Laboratory weight losses might be interpreted in terms of pit depths if it could be shown that a correlation existed between weight loss and maximum penetration on ferrous specimens after field exposure. To test this possibility, two specimens of each of four commonly used wrought ferrous materials, previously described, exposed for 10 years at 58 National Bureau of Standards test sites were chosen. Following the statistical procedure already referred to, the average depths* of the deepest pits on these specimens were correlated with the average weight losses. The coefficient of correlation was calculated to be 0.79. The equation, based on this correlation, relating weight losses and pit depths for the 58 soils after 10 years of exposure is

$$P_{10} = 5.2\,W_{10} + 36, \qquad (2$$

where $P_{10}$ is the maximum pit depth in mils on an area of 0.4 ft² and $W_{10}$ is the weight loss expressed in ounces per square foot. The standard error of estimate pertaining to $P_{10}$ in this equation is ±18 mils. Because of the number and variety of soils included in the derivation of eq (2, the relationship might be considered as being generally applicable to wrought ferrous materials exposed to any soil. Additional evidence of some correlation between weight loss and pitting on wrought and also cast ferrous specimens is indicated by the studies of Denison and Romanoff.[6]

By combining eq (1 and (2, the maximum antici-

* The average of the deepest pits on eight specimens is also referred to as the maximum pit depth.

pated pit depth at 10 years is related to the laboratory weight loss for six months by the relation

$$P_{10} = 43.9w + 30, \quad (3$$

where $P_{10}$ is expressed in mils at 10 years on an exposed area of 0.4 ft² and $w$ is as expressed for eq (1. Included in Table 4 are the actual maximum pit-depths measured on the field specimens and also the calculated values based on eq (3. The lack of reasonably good agreement in soil 5 is to be expected because of the facts previously pointed out concerning this soil.

### 5. Adjustment for Time and Exposed Area

It has been shown that by means of the laboratory corrosion test a reasonable estimate can be made of the weight loss and the average depth of the deepest pit that will occur on iron and steel specimens exposed in the field for 10 years. Obviously, the practical value of the test would be enhanced if it were possible to predict similar information as applied to larger exposed areas and periods of exposure other than 10 years.

Martin[12] has shown that the relation between the weight loss of iron and steel in soils and the duration of exposure may be expressed by the empirical equation

$$W = k' T^u$$

where $W$ is the weight loss at any time $T$, $k'$ is the weight loss on a unit area for a unit time and $u$ is a constant peculiar to the soil.

Similarly, Logan, Ewing, and Denison[4] have shown that the average depth of the deepest pits on iron and steel may be expressed by the empirical equation

$$P = kT^n A^a,$$

where $P$ is the average depth of the deepest pits at any time $T$ on the exposed area $A$, and $k$ is the average value of the depth of the deepest pits on specimens of unit area for a unit time. The exponents $n$ and $a$ are constants, $n$ depending on the aeration and drainage of the soil, and $a$ being relatively fixed in all soils.

For a practical application of these equations to any soil, appropriate values must be selected for the exponents. Logan, Ewing, and Denison tabulated values for exponent $a$ based on exposure tests of wrought ferrous specimens in 47 soils. They concluded that the value of $a$ could not be characterized by any particular soil property. As the values reported did not vary over too wide a range, the writer believes that some average value would be appropriate for all soils. By eliminating all soils in which the associated standard errors tabulated for $a$ exceeded 20 percent, the values of $a$ for the remaining 31 soils ranged between 0.082 and 0.241, averaging 0.15, with a standard error of 0.019.

Logan, Ewing, and Denison divided the 47 soils into four groups based on aeration and drainage and calculated the average value of the exponent $n$ for each group. These values of $n$ and the associated standard errors are shown in Table 5. Average values for $u$ and standard errors based on 14-year exposure tests of wrought ferrous materials by Denison and Romanoff[6] are included in the same table. It will be observed that the values of both $n$ and $u$ bear an inverse relation to the degree of soil aeration Also, if the values for $n$ and $u$ are compared, giving consideration to the standard errors, the mean values for $n$ and $u$ overlap, except for Group III. Because the values for $u$ are based on relatively few soils as compared with the values shown for $n$, the latter are taken to be the more significant. For this reason, because of what has already been shown concerning the correlation between weight loss and maximum penetration, the writer believes that the values for $n$ shown in Table 5 can be applied to $T$ in both the weight loss and pit-depth equations. Accordingly, this is proposed in Table 6, together with the distinguishing soil properties pertaining to the four groups.

Having obtained from the laboratory test a value for the average depth of the deepest pit at 10 years, $P_{10}$ on 0.4 ft² (eq 3), the value of pitting for a time $(T)$ other than 10 years and for an area $(A)$ greater than 0.4 ft² is calculated from the equation

$$P = P_{10} \left(\frac{T}{10}\right)^n \left(\frac{A}{0.4}\right)^{0.15} \quad (4$$

It has been pointed out by Logan, Ewing, and Denison that the values substituted for $T$ and $A$ cannot be chosen indiscriminately. This is particularly true when substituting for $A$, because $P_{10}$ applies to 0.4 ft². A reasonable extrapolation based on soils 55 and 56 (Table 4) might be considered. Assuming an area $(A)$ of 20 ft² (approx. 20 ft of 3½-inch steel pipe) and

**TABLE 5—Average Values of the Time Exponents n and u for Soil Groups Differing in Aeration**

| | $n$* | $\sigma_n$ | $u$* | $\sigma_u$ |
|---|---|---|---|---|
| Group I, Good Aeration | 0.19 | 0.03 | 0.23 | 0.10 |
| Group II, Fair Aeration | 0.35 | 0.03 | 0.42 | 0.12 |
| Group III, Poor Aeration | 0.47 | 0.04 | 0.74 | 0.14 |
| Group IV, Very Poor Aeration | 0.68 | 0.10 | 0.77 | 0.09 |

*Value for $n$ and the associated errors $\sigma_n$ are the mean values reported by K. H. Logan, S. P. Ewing, and I. A. Denison, Symposium on Corrosion Testing Procedures, ASTM (Phila. Pa., 1937). Values for $u$ and the associated standard errors $\sigma_u$ are average values taken from I. A. Denison and Melvin Romanoff, J. Research NBS 44, 47 (1950) RP2057.

**TABLE 6—Time Exponents n and u Associated with Soils of Different Properties**

| Soil Group | I | II | III | IV |
|---|---|---|---|---|
| Values, $n$ or $u$ | 0.19 | 0.35 | 0.47 | 0.68. |
| Aeration and drainage | Good | Fair | Poor | Very poor |
| Soil texture | Sands and sandy loams, light-textured silt loams, porous loams, clay loams. | Sandy loams, silt loams, clay loams. | Clay loams, clay | Clays and organic soils, including tidal marshes. |
| Depth of mottling in inches | None | 18 to 24. | 6 to 8. | 6 to 8. |
| Color of subsoil | Uniform. | Slightly mottled—yellowish brown and yellowish gray. | Moderately mottled—gray and bluish gray. | Mottled—bluish gray. |
| Height of water table | Very low | Low | 2 to 3 ft. below the surface | At the surface. |

an underground-exposure period *(T)* of 40 years, the maximum predicted pit depths calculated from eq (4 would be 112 mils, and 660 mils for soils 55 and 56, respectively. In these calculations, values of $n = 0.19$ and $n = 0.68$ were chosen for soils 55 and 56, respectively, the values being selected from Table 6 on the basis of the soil properties found in Table 1. Thus, in the case of soil 55 the increase in pit depth after 10 years is due chiefly to the increased area, whereas the deeper pits resulting from soil 56 are attributable mainly to the effect of time.

Weight losses at 10 years, based on the laboratory test (eq 1), can be similarly adjusted and values of weight loss *(W)* predicted for periods *(T)* other than 10 years. The weight loss becomes

$$W = W_{10}\left(\frac{T}{10}\right)^{u}, \qquad (5$$

where $u$ is selected from Table 6, based on the soil properties. The effect of area on weight loss is assumed to be linear. This equation is particularly useful in calculating the average penetration by conversion. Thus the average penetration in mils becomes

$$\bar{P} = 1.53\,W, \qquad (6$$

where $W$ is the weight loss in ounces per square foot (eq 5). The predicted average penetration on a steel surface exposed to soils 55 and 56 (Table 4) for 40 years would be 5 mils and 81 mils, respectively. Such information is useful where loss of strength is the primary consideration.

## 6. Summary

A modification of the Denison soil-corrosion cell is described. The cells were assembled in quadruplet with both steel and cast-iron electrodes exposed to 10 soils of varying degrees of corrosivity. Because the corrosion rate of ferrous metals in soils is a function of time all measurements are based on the weight loss of the electrodes after six months of exposure.

In nine of the soils, the steel electrodes lost less weight than the cast-iron electrodes. Statistically expressed, the difference in weight loss in five of these soils being due to chance was less than one percent and in two other soils less than four percent. The laboratory results compare favorably with 12-year field exposure tests.

Good correlation was also obtained between the weight losses of the corrosion cells and the weight losses occurring in the field on other wrought ferrous specimens exposed for 10 years to the same soils. Based on 10-year field exposure of wrought materials at 58 test sites throughout the United States, a fair correlation was found to exist between weight loss and maximum penetration. By making use of the latter correlation, it is shown how laboratory weight losses can be used to predict probable maximum pit depths on ferrous materials upon field exposure after 10 years.

By utilizing equations relating weight loss of ferrous field specimens to time of exposure, and the average depth of the maximum pits on the specimens to time and to exposed area, values of weight loss and pitting at the end of 10 years predicted by the laboratory test may be extrapolated to any desired area and period of exposure within reasonable limits. Suggested values of the exponents required for adjustment of the data are given.

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## 8. Appendix

### *8.1. Preparation of the Corrosion Cell*

The apparatus for moistening and adjusting the water content of the soil samples is shown diagrammatically in Figure 3. Because four cells are desirable for testing a soil, the apparatus provides for simultaneously moistening the soil contained in eight Lucite cylinders. Distilled water absorbed from the water dispenser, 12, resting on the upper surface of the soil, 9, is distributed uniformly throughout the soil by a pressure difference of 30 cm of Hg. Suction is applied to 500-ml suction flasks, 3, through fritted-disk Buechner funnels, 1, (150 ml, fine) to the soil contained in the Lucite cylinders, 7. Paraffin, 8, serves to confine the suction to the soil. The battery of eight suction flasks are connected to the suction apparatus with rubber tubing and glass fittings. The vacuum in the line is controlled by valve, 5, and to each flask by valve, 4.

Details of a water dispenser, 12, are shown under detail C, Figure 3. The reservoir, A, is cut from Lucite tubing of 1.75-inch OD and 0.125-inch wall thickness. The bottom edge, B, is tapered or rounded so that it will fit readily into the cylinder containing the soil. The dispenser is assembled as follows: With the reservoir placed on a flat surface in the position shown, asbestos paper, C, 0.125 inch thick cut into the form of a disk slightly larger than the inside diameter of the tubing, is pressed from the top to the bottom and sealed with molten beeswax, D. A saucer shaped stainless steel screen (16 mesh), E, held in place by friction and beeswax, serves to keep the weight of the glass beads, F, off of the asbestos. The beads (6-mm solid glass) added to within ½ inch from the top of the dispenser furnish weight to insure good contact for absorption of water by the soil. A second screen, G, identical with screen E, is pressed over the glass beads to prevent their loss.

The cell electrodes (Figure 1) are prepared for the corrosion tests in the following manner: The electrodes are degreased and all burrs removed with 1G French emery cloth. After being weighed, the electrodes are fitted with 0.5 inch × 2–56 steel fillister head machine screws and stranded copper wire (RC No. 18) leads, approximately 8 inches long are soldered under the heads. The edges and unfinished surfaces of the anodes are given a heavy coat of bituminous paint. The edges and unfinished sides of the cathodes, excluding the cylindrical surface of the holes, are similarly treated. The machine screws and soldered connections are also coated to prevent corrosion and to facilitate removal of the screws at the conclusion of the test.

In setting up the corrosion cells eight Buechner funnels, 1, are fitted with rubber stoppers, 2, and positioned as shown in Figure 3. Two sheets of filter paper (No. 42—5.5-cm diam), 6, are placed in each funnel to prevent direct contact between the soil and the fritted glass. The screw holes in the Lucite cylinders, 7, are filled with saturated soil and a cylinder is centered in each funnel. Paraffin is heated just to the melting point and a sufficient amount applied with a dropper to the space around each of the cylinders to adhere to both the funnel and the cylinder. Dry soil previously passed through a No. 20 standard sieve is poured into each cylinder approximately to the upper edge of the ridge and compacted by placing a cylindrically shaped brass weight 1.75 inches in diameter and 2.25 inches long on the surface of the soil. Disks of stainless-steel wire mesh (16-mesh), 10, are then placed on the ridges of 4 of the 8 cylinders and the process of filling the cylinders and compacting the soil is resumed until all of the cylinders are filled. As excessive swelling usually accompanies the moistening of heavy clay soils, allowance for this may be made by filling the cylinders just short of capacity.

After the asbestos of the water dispensers is saturated with distilled water, 15 ml of water are poured into each of the reservoirs and the dispensers then positioned on the surfaces of the soil samples but separated therefrom by a sheet of filter paper, 11, cut to conform to the inside diameter of the cylinder.

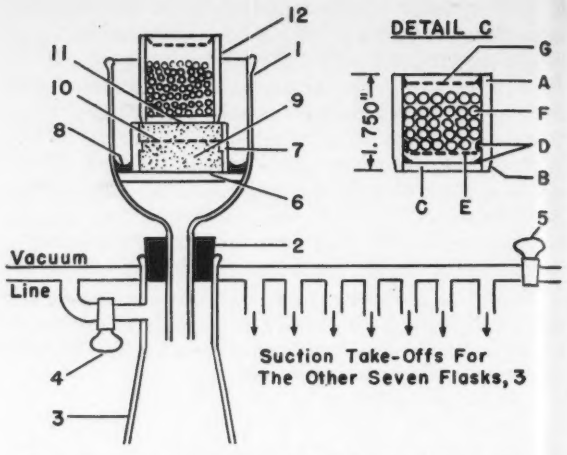


Figure 3—Cross-sectional view of the soil-moistening apparatus.

Vacuum equivalent to 30 cm of Hg is then applied for periods ranging from 1 to 8 hours, depending on the soil texture. Sufficient moistening of the soils is indicated by water dripping from the funnels, sweating underneath the fritted glass, or by the appearance of the soil. The valve, 4, to the particular cell is then closed and the water dispensers removed. Usually, all sections are sufficiently wet within 20 percent of the average wetting time peculiar to the soil. If it is necessary to delay assembly of the cell, evaporation of water can be prevented by covering the soil with a pad of cheesecloth saturated with water and the funnel with an inverted crystallizing dish.

The cell components are assembled in the following manner: The adhesion between the paraffin around the Lucite cylinders and the funnels is broken with a spatula, and the four funnels containing the cylinders fitted with the screen disks D, are removed. The four funnels are inverted, and the cell sections are dropped into the palm of the hand. The four cylinders, paper-capped ends down, are placed on a flat surface and the soil on the upper surface of the cylinders is slicked over with a spatula occasionally dipped into distilled water until all evidence of porosity has disappeared. The unpainted surfaces of four anodes (A, Figure 1) are lightly scratched with 1G French emery cloth and cleaned with distilled water. The anode is again moistened with distilled water, the screw aligned with the notch in the Lucite cylinder, and with an oscillatory motion combined with some pressure, the anode is placed in good contact with the soil. Excess soil is then removed, the components wiped dry, and the junction of the anode and the cylinder sealed with molten asphalt. The paraffin seal around the Lucite is loosened with a spatula, and the cylinders are turned over so as to rest on the anodes, after which the filter paper and adhering paraffins are lifted off in preparation for the positioning of the cathodes.

The cathodes (B, Figure 1) are prepared in the manner described for the anodes and positioned over the soil in the ends of these four inverted cylinders, previously described, with the uncoated surfaces facing the anodes. The cathode perforations are then filled with dry soil. The four remaining soil cylinders are removed from the funnels and positioned over the cathodes so that the edges from which the paraffin was removed are adjacent to the cathodes. The screen disk, E, is positioned, and the components are joined with molten asphalt, as shown in Figure 1. The rubber stopper, H, is then placed in position and held firmly against the anode by a No. 32 rubber band, G, wrapped once around the stopper and the cell. Each cell is placed on nonconducting supports in a 1-quart friction-top can containing about 25 ml of water to maintain a saturated atmosphere. The water level is maintained throughout the period of the test. Leads from the cell are passed through holes in the side of the can and the electrodes short-circuited by a Fahnestock clip soldered to one of the wires.

# Basic Criteria for Evaluating Some Plastic Materials of Construction *

By RAYMOND B. SEYMOUR*

**Abstract**

Fundamental information about plastic materials as to their generic characteristics is followed by a discussion of the atomic construction of the principal classes of plastics. Differences in the chemical resistance of polar and nonpolar materials are explained. Physical properties of some of the principal plastics are listed. After a brief history of the origin of the so-called synthetic or artificial plastics, 30 of the principal plastic materials are considered with respect to their atomic composition, resistance to corrosives, techniques for use, and some of the principal uses of each as structural materials.

TO SOLVE corrosion problems properly, an engineer must have a working knowledge of cathodic protection, corrosion inhibitors, ceramics, metals, wood and plastics. Obviously, few can assimilate this wide variety of information but all corrosion engineers should be acquainted in a general way with the main tools that are available for counteracting corrosion.

Because most courses in corrosion prevention are taught by metallurgists, too few corrosion engineering students learn the fundamentals of nonmetallic materials of construction. In most instances, knowledge of other techniques is accumulated from advertisements and trade journals and interviews with salesmen. Such methods of learning are invaluable, providing the student has received previously sufficient fundamental training to permit its proper evaluation.

Some corrosion engineers consider organic protective coatings and plastics to be synonymous. Yet the former constitutes but one end use of chemical resistant plastics. Unfortunately, the "Hollywood approach" in advertising and selling has been applied too often to protective coatings. As a result, the consumer often forgets relative costs and sometimes expects a few coats of a poorly applied protective coating to make mild steel outlast expensive alloys, in the presence of corrosive liquids.

It is sincerely hoped that the information presented herein will permit the corrosion engineer not only to solve problems through the use of a wider selection of materials but also aid him in the evaluation of corrosion data obtained. It is assumed that the plastics approach will be used more frequently when the type of knowledge presented herein is more widely available. However, it should be emphasized that plastics should be used only if no other material will solve the problem as well when evaluated under identical conditions.

While plastics will not perform miracles, they will in a large number of instances prove superior to all other known materials in counteracting the action of corrosive chemicals. Because it is of utmost importance to know deficiencies as well as advantages of all proposed materials, an attempt is made herein to present broad practical knowledge which should aid in bringing about a sound evaluation of plastics as materials of construction.

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## Plastics Fundamentals

Plastics may be defined scientifically in terms of rheology but for the purpose of this presentation, they may be considered as high molecular weight organic materials which, in the hands of properly instructed mechanics, can be formed into specific shapes. In the broadest sense, plastics may be shaped by molding or extrusion but those materials most useful for the solution of corrosion problems must be formed and shaped through the use of less expensive and simpler tools. Often the change in form must take place under conditions that are far from ideal under the guidance of painters, carpenters or bricklayers who are usually unskilled in plastics know-how.

A simple melting and cooling technique can be applied to a few specific plastic materials, such as asphalt, coal tar pitch and plasticized sulfur cements. Other plastics may be dissolved in solvents or dispersed in liquids which may be either solvents or non-solvents. Most protective coatings are primarily solutions of plastics in organic solvents. The proper application of such coatings necessitates the removal of the solvent liquid at room temperature or at elevated temperatures. A third method which, in contrast to the melt and solution techniques, is usually an irreversible process, makes use of a catalyst to change a low molecular weight liquid to a high molecular weight solid. Phenolic and furan cement mortars and polyester compositions make use of such insolubilizing catalyst techniques.

No product should be recommended as a material of construction unless it is completely resistant to the chemical environment expected under service conditions and has adequate physical properties to withstand the most drastic conditions anticipated in service. If the physical properties are deficient, it is often possible to bolster the construction through reinforcements but if the proposed material is not completely chemical resistant, it should not be used except on a provisional basis. The structural engineer makes use of a factor of safety to compensate for

design errors. The corrosion engineer must adopt a similar approach and whenever completely chemically resistant products are available, learn to refuse to accept materials that are only partially chemical resistant.

In addition to being chemically inert and having adequate physical properties, the ideal material of construction should be: 1) economical, 2) readily installed, 3) selected on the basis of long term field experience, 4) free from objectionable odors, 5) nontoxic to the workmen, 6) not subject to damage during storage, and 7) readily available commercially.

Plastics which have molecular weights in the order of 10,000-1,000,000 differ from ordinary chemical compounds with molecular weights usually less than 200. Plastic molecules consist of long chains with regularly recurring groups. These chains usually consist of several thousand carbon atoms joined to each other.

Products consisting of molecules made up of straight chains can be softened with heat and are termed thermoplastic or two-dimensional plastics. Those whose structure consists of a network of interconnecting chains are called thermosetting plastics. They are not softened by moderate heat and are usually solvent-resistant. They are three-dimensional in structure. A thermoplastic may be compared to a piece of pipe in contrast to a jungle gymnasium which may be likened to a thermosetting plastic.

Most thermoplastics are formed by addition polymerization of an unsaturated material in the presence of heat and/or catalyst. Addition polymerization is a simple chain lengthening process in which small units continue to add to a growing chain-like molecule. Most polymerization catalysts are peroxy compounds, such as benzoyl peroxide or potassium persulfate. An unsaturated molecule is one that contains double bonds, such as ethylene.

In contrast, most thermosetting plastics are formed by the condensation of one compound with another in which a simple product, such as water is eliminated from the reaction. Thermoplastics usually can be softened and reformed whereas thermosetting materials are not softened to any great extent below the decomposition temperature.

Cellulose, rubber, shellac and casein are natural products. Derivatives of natural products, such as cellulose nitrate, ethyl cellulose, and chlorinated rubber are termed artificial. Most other plastics are synthetic. The simplest unsaturated compound is ethylene. If one of the hydrogens in ethylene is replaced by chlorine, the product becomes vinyl chloride.

Each of these unsaturated polymerizable products is called a monomer. If ethylene is polymerized, polyethylene is produced. When two monomers are polymerized simultaneously, a copolymer is usually formed. A copolymer is not a mixture but contains both monomeric materials in the polymer chain.

There are many other terms used by polymer chemists but a knowledge of those outlined above should be sufficient to aid the non-chemist in understanding a few fundamentals of plastic technology so that he may not be confused when plastics are being considered as corrosion resistant materials.

## Chemical Resistance

Information on methods of testing and specific chemical resistance of plastics will be discussed later. It is well to suggest at this time that considerable knowledge of chemical resistance may be determined from an examination of chemical structure. In general, corrosives and plastics may be divided on the basis of polarity into polar and non-polar materials. Like materials attract and unlike materials repel and this general rule may be used as a guide to predict the effect of corrosives on plastics. Obviously, a knowledge of the nature of both the chemical environment and the plastic structure is required in order to make use of this rule.

Plastics having polar groups, such as hydroxyls (OH), carboxyls (COOH) and methoxy groups ($OCH_3$) are usually swollen or even dissolved by polar materials, such as water and ethyl alcohol. In contrast, polar plastics products are resistant to non-polar organic solvents, such as gasoline, benzene or carbon tetrachloride.

As might be assumed from the previous statement, plastics having a large number of non-polar groups, such as chlorine (Cl), hydrogen (H) and phenyl ($C_6H_5$) are resistant to polar solvents, such as water and ethyl alcohol but are usually swollen or dissolved by non-polar solvents, such as gasoline, benzene or carbon tetrachloride.

Acids, alkalies and salts are polar; whereas, most solvents, except water, alcohol, glycols and glycerol, are non-polar. In general, plastics that have outstanding corrosion resistance usually contain a plurality of non-polar groups. Gelatin, casein, starch, methyl cellulose, carboxy methyl cellulose, hydroxyethyl cellulose, polyethylene glycols and polyvinyl alcohol are all high molecular weight plastics but are seldom considered as corrosion resistant materials because as shown by structural formulas for chain segments in Table I, these materials contain a large number of polar groups. Structural formulas are shown to illustate the effect of specific groups in the polymers. Explanation of specific structural formulae is beyond the scope of this discussion.

In contrast to the more polar polymers polyethylene, polyisobutylene, asphalt, coal tar pitch, coumarone-indene resins, polystyrene, polymers or copolymers of vinyl chloride or vinylidene chloride, polychlorotrifluoroethylene, polytetrafluoroethylene, natural rubber, butyl rubber, neoprene, phenolic resins and furan resins are generally resistant to non-oxidizing acids, salts and alkalies but are less resistant to organic solvents than the more polar materials. As might be concluded by reference to their chemical formulas, nylon, saturated polyesters, cellulose acetate and ethyl cellulose occupy an intermediate position in that they are less resistant to corrosive chemicals but are more solvent resistant due to their somewhat polar nature.

In addition to polarity, the resistance of reactive groups in plastic molecules to specific chemicals also must be considered. Water, alcohol, benzene and other organic solvents may dissolve a plastic but neither these nor neutral salts react chemically with the plastic molecule. However, more active chemi-

cals, such as sodium hydroxide, hydrochloric acid and nitric acid may attack specific groups. For example, alkaline materials, such as aqueous sodium hydroxide, may saponify esters, such as those found in cellulose acetate, cellulose acetatebutyrate, oil base paints, polyvinyl acetate, polymethyl acrylate and polyesters. Likewise, alkalies may hydrolyze cyano groups, such as those found in polymers of acrylonitrile and react with acidic hydroxyl groups, such as those found in phenolic resins. Non-oxidizing acids, such as hydrochloric and phosphoric acids may hydrolyze these materials in much the same manner. In addition, hydrochloric acid may react with unsaturated plastics, such as natural rubber to form products whose properties will differ from the original plastic.

The oxidizing chemicals, such as concentrated sulfuric acid, chromic acid and chlorine dioxide may oxidize almost any oxidizable group, such as those found in phenolic resins, furan resins and natural rubber. Strong nitric acid and chlorine may actually nitrate or chlorinate specific materials, such as polystyrene, coumarone-indene resins and phenolic resins. Concentrations and temperatures of the chemicals, of course, should be considered but these factors are relatively less important than the ability of the corrosives to react with specific groups.

In addition to considering the chemical make-up of the plastic material itself, it is essential to know also the chemical resistance of all fillers, stabilizers, plasticizers and other additives present in the plastic material. Cellulosics, such as wood flour, and mineral carbonates, such as ground limestone are not recommended as fillers for corrosion resistant plastics. Silica, glass and asbestos often are used as fillers or reinforcing agents but are not recommended when the plastic product is to be used in the presence of strong alkalies, hydrofluoric acid or hydrofluosilicic acid.

While a final evaluation of chemical resistance cannot be made until specific materials are tested under actual service conditions, considerable useful information can be secured by evaluating the resistance of a plastic structure to the following typical chemicals:

**POLAR:**

Water ..... $H_2O$
Salts: 10% Sodium Chloride ..... NaCl
Alkalies: 10% Sodium Hydroxide ..... NaOH
Non-Oxidizing Acids: 25% Sulfuric Acid .... $H_2SO_4$
Oxidizing Acids: 50% Nitric Acid ..... $HNO_3$

**NON-POLAR:**

Aliphatic Solvent: ..... Kerosene
Aromatic Solvent: ..... Toluene, $C_6H_5CH_3$
Chlorinated Solvent:
Ethylene Dichloride ..... $ClCH_2—CH_2Cl$
Vegetable Oil: ..... Cotton Seed Oil

## Physical Properties

Next to chemical resistance, possibly the next most important advantage of plastics over other materials of construction is their low specific gravity. The specific gravity of plastics varies from 0.9 for polyethylene to 2.3 for polytetrafluoroethylene. These values compare favorably with the lightest metals whereas commonly accepted corrosion resistant metals, such as stainless steel alloys, have specific gravities ranging from four to ten times these two extremes.

The tensile strength of plastics varies from less than 2000 psi for polyethylene and polytetrafluoroethylene to over 40,000 psi for glass reinforced polyesters and highly oriented crystalline polymers, such as saran and nylon fibers. The latter value, of course, is in the range of steel and considerably stronger when this value is considered on a weight rather than a volume basis. However, in contrast to many metals, plastics have temperature limitations, high notch sensitivity and exhibit creep under load. These deficiencies must be considered in any design where plastic materials are proposed.

Of course, creep values for filled thermosetting plastics are lower than unfilled thermoplastic products and the ductility which is associated with creep often counterbalances this characteristic deficiency. Even though the tendency for creep in many plastics is less than that of lead, it is good practice to correlate the behavior of plastics with a ductile metal, such as lead. If this concept is kept in mind, design engineers will recognize the necessity for using factors of safety based on a practical knowledge of service conditions.

Many other physical properties, such as impact resistance, tensile strength, modulus of elasticity and deformation under load are correlated with creep and the effect of temperature on these properties must always be taken into consideration. With the exception of polytetrafluoroethylene and silicones, few plastics can be used at temperatures above 350 degrees F. Physical properties, such as coefficient of expansion, thermal conductivity, dielectric strength and weathering properties are characteristic for specific plastics. In general, plastics are better heat and electrical insulators than metals.

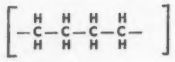
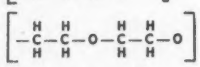
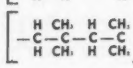
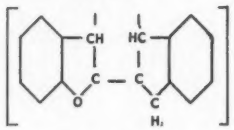
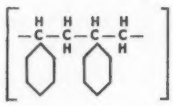
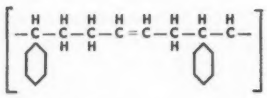
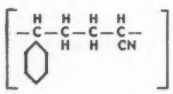
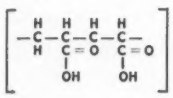
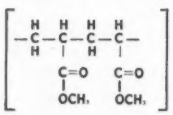
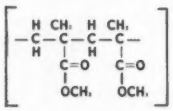
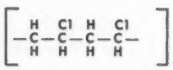
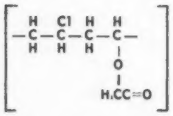
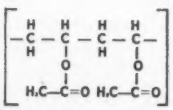
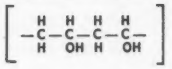
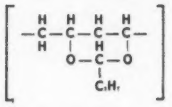
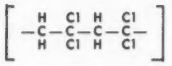
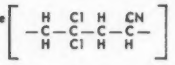
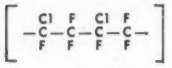
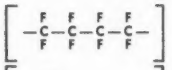
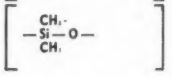
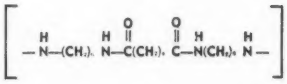
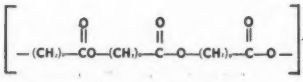
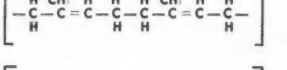
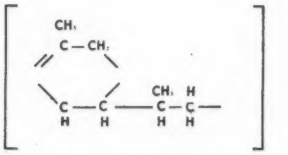
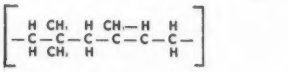
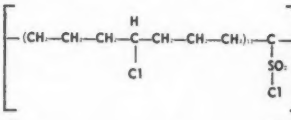
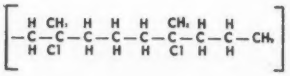
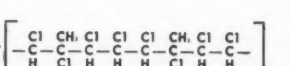
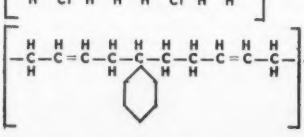
## History

Before considering the chemical constitution of specific plastics, it might be well to discuss the history of some of the basic plastics. Natural plastics, such as rosin, shellac, natural asphalt and cellulose have been known for centuries. Other naturally occurring plastics, such as casein and gilsonite, while available for many years, were not adopted commercially until recent years. Similarly, while rubber has been known for centuries, its derivatives, such as chlorinated rubber, isomerized rubber and rubber hydrochloride were not commercialized until recent years.

It might be anticipated that many of the first commercial plastics were artificial rather than synthetic in that they were chemical derivatives of natural plastics such as cellulose, rosin or rubber. While it is not intended to underestimate the chemists' contributions, it should be emphasized that many major improvements in plastic technology have been made by practical men who saw the possibilities of using specific products to solve problems.

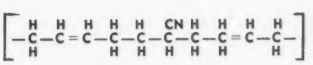
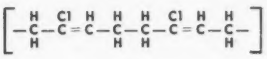
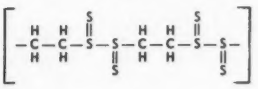
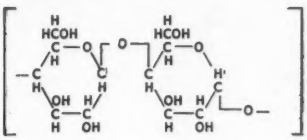
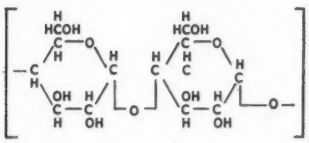
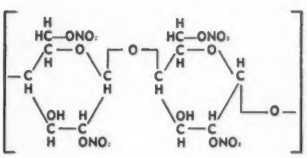
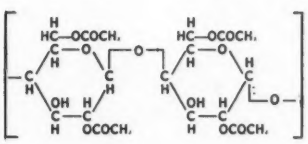
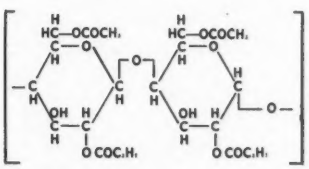
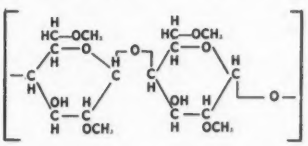
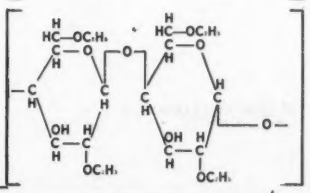
Thus, cellulose nitrate or nitrocellulose synthesized by Schönbein in 1846, was limited in use at first primarily to a solution of this product called

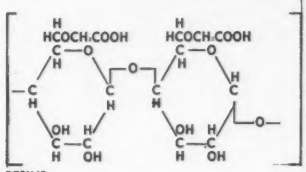
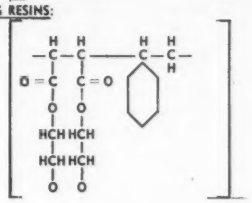
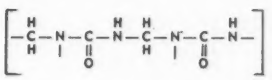
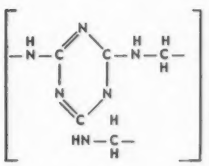
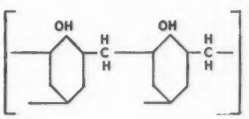
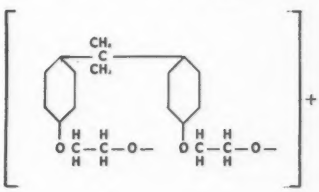
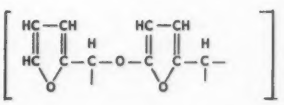
# Table 1—Molecular Structure and Chemical Resistance of Plastics

| Product | Formula | RESISTANCE* Water | Organic Solvents | Salts | Alkalies | Acids | Oxidizing Compounds |
|---|---|---|---|---|---|---|---|
| **THERMOPLASTICS:** | | | | | | | |
| Plasticized Sulfur | | + | − | + | − | + | − |
| Polyethylene |  | + | − | + | + | + | + |
| Polyethylene Glycol |  | − | + | − | − | − | − |
| Polyisobutylene |  | + | − | + | + | + | + |
| Asphalt | Polycyclohydrocarbons | + | − | + | ± | + | − |
| Coal Tar Pitch | Aromatic Hydrocarbons | + | − | + | + | + | − |
| Coumarone-Indene Resins |  | + | − | + | + | + | − |
| Polystyrene |  | + | − | + | + | + | − |
| Styrene Butadiene Copolymer |  | + | − | + | + | + | − |
| Styrene Acrylonitrile Copolymer |  | + | − | + | − | + | − |
| Polyacrylic Acid |  | − | + | ± | − | − | − |
| Polymethyl Acrylate |  | + | ± | + | − | ± | − |
| Polymethyl Methacrylate |  | + | ± | + | + | + | − |
| Polyvinyl Chloride |  | + | ± | + | + | + | + |
| Vinyl Chloride—Vinyl Acetate Copolymer |  | + | ± | + | + | + | ± |
| Polyvinyl Acetate |  | ± | − | + | − | − | − |
| Polyvinyl Alcohol |  | − | + | − | − | − | − |
| Polyvinyl Butyral |  | + | − | + | + | + | − |
| Polyvinylidene Chloride |  | + | ± | + | + | + | + |
| Vinylidene Chloride—Acrylonitrile Copolymer |  | + | ± | + | − | + | + |
| Polychlorotrifluoroethylene |  | + | + | + | + | + | + |
| Polytetrafluoroethylene |  | + | + | + | + | + | + |
| Silicone |  | + | − | + | − | − | − |
| Nylon |  | + | + | + | ± | − | − |
| Saturated Polyester |  | + | − | + | − | + | − |
| **NATURAL AND SYNTHETIC RUBBERS AND DERIVATIVES:** | | | | | | | |
| Natural Rubber |  | + | − | + | + | + | − |
| Isomerized Rubber (Thermoprene) |  | + | − | + | + | + | − |
| Butyl Rubber |  | + | − | + | + | + | + |
| Chlorosulfonated Polyethylene |  | + | − | + | + | + | + |
| Rubber Hydrochloride |  | + | − | + | + | + | − |
| Chlorinated Rubber |  | + | − | + | + | + | − |
| Styrene Rubber |  | + | − | + | + | + | − |

* + = No apparent attack under normal conditions.
± = Attack by some, but not all chemicals in this class under normal conditions.
− = Considerable attack under normal conditions.

# Table 1—Molecular Structure and Chemical Resistance of Plastics

| Product | Formula | RESISTANCE* Water | Organic Solvents | Salts | Alkalies | Acids | Oxidizing Compounds |
|---|---|---|---|---|---|---|---|
| Acrylonitrile Rubber |  | + | ± | + | − | + | − |
| Neoprene |  | + | − | + | + | + | − |
| Polysulfide Rubber |  | + | ± | + | ± | + | − |
| **CELLULOSE AND ITS DERIVATIVES:** | | | | | | | |
| Cellulose |  | ± | + | + | ± | ± | − |
| Starch |  | − | + | − | − | − | − |
| Cellulose Nitrate |  | + | − | + | ± | + | − |
| Cellulose Acetate |  | + | − | + | − | ± | − |
| Cellulose Acetate Butyrate |  | + | − | + | − | ± | − |
| Methyl Cellulose |  | − | + | − | − | − | − |
| Ethyl Cellulose |  | ± | − | + | + | ± | − |

| Product | Formula | RESISTANCE* Water | Organic Solvents | Salts | Alkalies | Acids | Oxidizing Compounds |
|---|---|---|---|---|---|---|---|
| Carboxy Methyl Cellulose |  | − | + | − | − | − | − |
| **THERMOSETTING RESINS:** | | | | | | | |
| Unsaturated Polyester |  | + | − | + | − | + | ± |
| Urea Resin |  | + | + | + | + | ± | − |
| Melamine Resin |  | + | + | + | + | ± | − |
| Phenolic Resin |  | + | + | + | − | + | − |
| Epoxy Resin |  | + | ± | + | ± | + | − |
| Furan Resin |  | + | + | + | + | + | − |

* + = No apparent attack under normal conditions. ± = Attack by some, but not all chemicals in this class under normal conditions. − = Considerable attack under normal conditions.

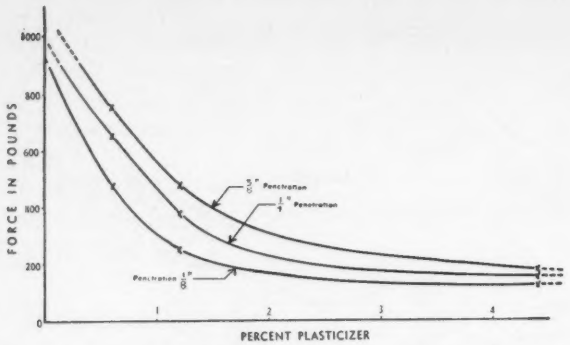



**Figure 1—Relation between ductility in sulfur cements and plasticizer content. Tests were made by measuring force required in pounds for penetration of a ⅛-inch rod to ⅛-inch, ¼-inch and ⅜-inch.**

| Plasticizer % | Force in Pounds | | |
|---|---|---|---|
| | ⅛" | ¼" | ⅜" |
| 0 | 900+ | 900+ | 900+ |
| 0.6 | 475 | 650 | 750 |
| 1.2 | 250 | 375 | 475 |
| 4.4 | 120 | 150 | 175 |

Collodian. It remained for a printer named John W. Hyatt to visualize the practicability of mixing cellulose nitrate with camphor in order to form a plastic product which he termed Celluloid. The use of cellulose acetate as a less flammable alternate to Celluloid seems quite obvious yet such a material was not commercialized until 1927.

From the standpoint of economics and practicability, Dr. Leo Baekeland doubtlessly made one of the greatest contributions to the plastics industry. Admittedly, in combining phenol and formaldehyde, he modified previous laboratory practice very little but unlike previous investigators in this field, he foresaw the practical value of his invention. Perhaps the next greatest achievement in plastics technology was made by Dr. Wallace Carothers, who, through an understanding of fundamental concepts, was able to lay the ground work for neoprene, nylon and polyester plastics. Hundreds of other pioneers deserve credit, of course, but the foundation for many of the other discoveries was based on the pioneering achievements of Hyatt, Baekeland and Carothers.

In passing, it should be emphasized that the full usefulness of plastics is far from being realized. In spite of what conservative plastics technologists believe, many frontiers still exist in the plastics field. To imaginative minds, it appears obvious that in spite of the chemists' past success in developing many commercial plastics, plastics technology still is in its infancy. The commercialization of polyethylene, polytetrafluoroethylene, polyesters, epoxy resins and silicones during the past fifteen years should convince the skeptics that this industry is far from static.

### Plasticized Sulfur

While sulfur is not usually considered a plastic material, plasticized sulfur meets most of the requirements of a plastic since it is ductile and can be formed by heat. Commercial products containing it which have been available for a least 25 years have the chemical resistance of sulfur but are much stronger, more ductile and more useful. Most commercial sulfur compounds consist of 50-60 percent sulfur and the remainder primarily of graded silica or carbon aggregate plus suspending agents and plasticizers. Carbon black usually is added to minimize settling of the filler while the cement is in the molten state and plasticizers, such as polyolefin sulfides have been used to give ductility. Since the latter property is based primarily on the plasticizer content, it can be varied widely by increasing or decreasing the amount of plasticizer present as shown by the accompanying graph in which the force required for penetration of a ⅛-inch diameter rod to a specific depth is inversely related to the plasticizer content.

Because sulfur changes its crystalline form from rhombic to monoclinic at 96 degrees C (205 degrees F) and these two forms have different specific gravities, sulfur cements must not be used above this critical temperature. Likewise, because sulfur is soluble in many organic solvents and attacked by alkaline solutions, it cannot be used in the presence of most solvents nor at a pH greater than 10. Sulfur can be oxidized to sulfur dioxide and hence, it should not be used in highly oxidizing media. However, it is completely resistant to all non-oxidizing acids and salts.

### Polyethylene

While from a chemical structure point of view, polyethylene is one of the simplest plastics, it cannot be manufactured by standard polymerization techniques. Polyethylene was produced first commercially by Faucett and coworkers by the polymerization of ethylene under pressure in the presence of small amounts of oxygen. A review of the empirical rules on chemical resistance will indicate that polyethylene should be one of the most resistant materials to chemicals at ordinary temperatures. Because of the simplicity of its manufacture and its high chemical resistivity, it may be predicted that polyethylene will become one of the most important plastics of the future.

In general, one may consider polyethylene as a high molecular weight paraffin. It has low water solubility, low specific gravity, good electrical properties and good resistance to most acids, salts and alkalies. It is swollen but not completely dissolved by many organic solvents.

Polymers of ethylene oxide differ from polyethylene in having ether linkages and terminal hydroxyl groups present. Because of increased polarity these products, called polyethylene glycols, are actually water soluble and are not used for chemical resistant construction.

### Polyisobutylene

While polyisobutylene has been known since 1873, the high molecular weight commercial product was not developed until 1937 when a patent was issued to Otto and Mueller-Cunradi. Polyisobutylene is produced by the polymerization of isobutylene in the presence of aluminum chloride or boron trifluoride at temperatures in the order of —100 degrees C (—148 degrees F). As in other addition polymerization reactions, the high molecular weight products

are produced at lower temperatures, thus, a product having a molecular weight of around 10,000 may be produced at —10 degrees C (14 degrees F) while the product produced at —100 degrees will have a molecular weight in the order of 200,000.

As is evidenced from its formula, polyisobutylene is quite similar in structure to polyethylene. However, the methyl groups present on the polymer chain, produce greater flexibility and decrease the chemical resistance somewhat. Since polyisobutylene is considerably less resistant to heat and is quite tacky, its use in this country has been primarily for adhesives and chewing gum. However, carbon-filled polyisobutylene is used widely in Germany as a tank lining.

### Asphalt

Since asphalts are naturally occurring materials, they were used centuries before the development of modern materials of construction. There is some controversy over definition since attempts have been made to differentiate between natural occurring asphalts, such as gilsonite, grahamite and glance pitch from the petroleum asphalts. For simplicity, all asphalts may be considered to be colloidal systems consisting of minor amounts of carbon and polycyclic compounds soluble in carbon disulfide. Most asphalts contain some acidic constituents. They are attacked by sodium hydroxide but are resistant to most non-oxidizing acids and corrosive salts. As might be predicted from a consideration of structure, they are attacked by concentrated sulfuric acid and dilute nitric acid. The structure of asphalts is too complicated to permit accurate representation by formulas.

The most widely used asphalts are based on petroleum residues, the specific constitution of which depend upon the source of the crude oil. One of the oldest natural occurring asphalts found at Lake Trinidad contains as much as 40 percent clay. Other natural occurring asphalts are gilsonite, glance pitch, rafaelite and grahamite. Elaterite and wurzilite are similar in chemical properties to the other asphalts but are much less soluble in organic solvents. Contrary to general belief, there is no great difference in the usefulness of comparable synthetic and natural asphalts. The physical and chemical constants of an asphalt are much more significant than datum on its origin.

Asphalts are used as filled and unfilled melts, as solutions in organic solvents and as aqueous dispersions. Much asphalt is used in road building and waterproofing but considerable quantities also are used in chemical resistant construction.

### Coal Tar Pitch

Coal tar pitch may be classified with petroleum asphalt. It is, of course, a product of indefinite composition whose chemical and physical properties are dependent to a large extent upon the degree of distillation during production. Because it is essentially aromatic hydrocarbon in nature, the chemical constitution of coal tar pitch differs from asphalt, which is composed primarily of cycloparaffins. However, the physical properties of the two materials are somewhat similar. Coal tar pitch is slightly soluble in aromatic solvents and less heat stable than asphalt.

Like asphalt, coal tar pitches are used as hot melts, solutions in organic solvents and aqueous emulsions. The main use of coal tar pitch is in filled caulking compositions and in inexpensive coal tar coatings. The latter find considerable use in the protection of pipe lines.

### Coumarone-Indene Resins

That coumarone and indene could be isolated from coal tar naphthas and polymerized to solid materials in the presence of sulfuric acid was demonstrated in 1890 by Kraemer and Spilker. While commercial production of these resins was not undertaken until 1920, present output exceeds 20,000,000 pounds annually. Structural formulas for polycoumarone and polyindene are not given separately in Table I because most commercial products are copolymers of both materials.

Coumarone-indene resins are melted readily and are soluble in a wide variety of solvents. They are used widely in the compounding of rubber and for the manufacture of varnishes, floor tile and printing inks. They are resistant to most non-oxidizing acids, salts and alkalies but are not used extensively in chemical resistant construction.

### Polystyrene

Styrene was first polymerized by Simon in 1839 and while known in the laboratory for over a century it was available commercially in this country until 1937. It is now produced in large quantities by the polymerization of styrene which, in turn, is manufactured from benzene and ethylene. As might be concluded from its structure, polystyrene is soluble in most organic solvents with the exception of the more polar solvents, such as alcohol and glycerol. It is completely resistant to non-oxidizing acids, salts and alkalies but is attacked by chlorine, chromic acid, nitric acid and concentrated sulfuric acids. Polystyrene has a low specific gravity, low water absorption and excellent dielectric properties. The principal deficiency of polystyrene is its brittleness which minimizes its usefulness for chemical resistant construction. As will be evident from subsequent discussion, this deficiency has been overcome through modifications of this polymer.

### Styrene Copolymers

The most widely used styrene copolymers are those with 20-40 percent butadiene and 15-30 percent acrylonitrile. As might be concluded from its structural formula, the chemical resistance of the butadiene copolymer is much the same as that of polystyrene. The butadiene group lends flexibility to the molecule and this copolymer is much less brittle than polystyrene. It is widely used in the form of aqueous emulsions and solutions in organic solvents as a water-type paint and protective coating respectively.

Copolymers of styrene and acrylonitrile have better impact resistance than polystyrene but have somewhat poorer resistance to acids and alkalies. These copolymers usually are blended with acrylon-

itrile rubber in order to improve their impact resistance. The chemical resistance of this blend is essentially the same as the copolymer. The blend is used widely for plastic pipe and to some extent for solvent welded and mechanically joined plastic structures.

### Acrylates

Commercialization of acrylic resins both in Germany and in this country was due to a large extent to the efforts of Rohm. The acrylates are somewhat rubbery and are seldom used in chemical resistant construction. They have good resistance to salts, fair resistance to acids but are readily saponified by alkaline solutions. Polyacrylic and polymethacrylic acids are water soluble and are not used in chemical resistant construction.

The methacrylates are more rigid and presumably because of steric hindrance, are not readily saponified. Methacrylates, such as polymethyl methacrylate, are available as clear sheets and are used in chemical resistant construction when a clear plastic product is required. Solutions of methacrylates have been used to a limited extent as protective coatings. Clear sheets of polymethyl methacrylate have been solvent or heat-welded to form equipment used in the plating industry.

### Polyvinyl Chloride and Copolymers

Much of the original development of polyvinyl chloride was based on the fundamental studies of Ostromysslenskii in the early part of the twentieth century. Because suitable plasticizers were not available, polyvinyl chloride was not manufactured commercially until about 1930. Surprisingly enough, almost a billion pounds of plasticizable polyvinyl chloride was produced before the superior advantages of the unplasticized material was recognized.

The differences between rigid non-plasticized polyvinyl chloride and ordinary polyvinyl chloride before plasticization is primarily in molecular weight and molecular weight distribution. The two products have essentially the same structural formula and chemical resistance. However, because the more widely used polyvinyl chloride must be plasticized so it can be extruded for use as chemical resistant equipment, its chemical resistance is lowered. Most commercial formulations for chemical resistant rigid unplasticized polyvinyl chloride and plasticized polyvinyl chloride are not attacked by non-oxidizing acids, salts and alkalies. The main difference between the unplasticized material and the plasticized commercial products is in the varying degrees of resistance to temperature and oxidizing materials.

In addition to plasticization, considerable improvement in processing characteristics has been also attained by copolymerizing other monomers with vinyl chloride. The most widely used material of this type is the copolymer of vinyl chloride with minor amounts of vinyl acetate. While the acetate group lowers the chemical resistance of the product, copolymers having as much as 13 percent vinyl acetate have sufficient chemical resistance to justify their use in many applications.

Unplasticized rigid polyvinyl chloride is used primarily for extruded pipe and heat-welded thermoplastic structures. Plasticized polyvinyl chloride is used for mechanical goods and sheet linings. Its insolubility prevents its use as a coating without the special formulations, such as organosols or plastisols. The vinyl chloride-vinyl acetate copolymer is used primarily in solutions which are usually termed vinyl coatings.

### Polyvinyl Acetals

Polyvinyl acetate has been produced commercially since 1920 using techniques developed by Klatte and Rollette a few years previously. Since it is hydrolyzed quite readily by acids and alkalies and has high moisture absorption, polyvinyl acetate is not used to any great extent in corrosion resistant construction. Mixtures of aqueous dispersions of polyvinyl acetate and hydraulic cements have been proposed as monolithic floor coatings.

Saponification of polyvinyl acetate produces water soluable polyvinyl alcohol. This product is used occasionally for solvent resistant tubing and gaskets. The water resistance of these products usually is improved by a surface reaction with formaldehyde.

Reaction of polyvinyl alcohol with a higher molecular weight aldehyde, such as butyraldehyde, yields acetals which are not soluble in water and have fair chemical resistance. Polyvinyl butyral is the plastic component of standard wash primer systems.

### Vinylidene Chloride Polymers

Vinylidene chloride and its copolymers with vinyl chloride and acrylonitrile are available under the generic name of saran. As indicated by the structural formula, vinylidene chloride is quite similar to vinyl chloride but has twice as many chlorine groups. Polymers of vinylidene chloride and copolymers in which other chemical resistant groups are present, are resistant to most non-oxidizing acids, alkalies and salts.

Saran copolymers sometimes are plasticized and filled with carbon to form flexible sheets. This product is less chemically resistant than the hard polymers and is not recommended for use with warm alkaline solutions. Polymers of vinylidene chloride also are used as pipes, tubing, valves and as aqueous dispersions and solutions for protective coatings.

### Polyfluoroethylene

Polychlorotrifluoroethylene and polytetrafluoroethylene are more expensive than the corresponding polyvinyl chloride but have superior resistance to oxidizing agents, solvents and high temperature. Polytetrafluoroethylene is somewhat more resistant than the polychlorotrifluoroethylene polymer but both are used widely as gaskets, diaphragms, valve seats and mechanical goods where outstanding chemical resistance is required. Both products have been used successfully at temperatures in the order of 400 degrees F even in the presence of nitric acid. Polytetrafluoroethylene is resistant to almost all chemicals except molten alkali metals and hot fluorine. They are available as molded or extruded parts

and as aqueous dispersions. Aqueous dispersions have been applied to various metal surfaces with subsequent baking to produce nonadhesive surfaces.

### Silicones

The silicone plastics differ from all other plastics in that they contain silicon rather than carbon atoms in the basic molecular structure. As might be expected, such plastics have outstanding heat resistance. Some have been reported to have been used continuously at temperatures in excess of 400 degrees F. These products have poor resistance to alkalies and solvents but have fair resistance to non-oxidizing acids. Their main use in chemical resistant construction is as gasket materials and as high temperature resistant coatings.

### Polyamides

Polyamide plastics were first recognized in 1899 by Gabriel and Manes, who prepared products of this general type of heating aminocaproic acids. This type of reaction was investigated further by Carothers who developed nylon by condensing adipic acid with hexamethylene diamine.

Nylon is insoluble in most solvents except hot formic and acetic acids and phenol. It is resistant to corrosive salts but is hydrolyzed by hot acids or alkalies. Polyamides have not been used to any great extent as corrosion resistant materials in the chemical industry.

### Natural Rubber

As one might expect from a study of its structural formula, natural rubber is not attacked by alkalies, corrosive salts or non-oxidizing acids with the exception of hydrochloric acid, which may add to the double bond present in the structure. Natural rubber is not satisfactory for use in the presence of non-polar solvents, such as vegetable and mineral oils, gasoline, benzene and carbon tetrachloride or in the presence of oxidizing substances, such as nitric acid, concentrated sulfuric acid, chromic acid, sodium hypochlorite and chlorine dioxide.

Unvulcanized rubber will cold flow at ordinary temperatures but vulcanized soft rubber may be used satisfactorily at temperatures up to 150 degrees F. Because hard rubber or ebonite contains fewer oxidizable double bonds, it is more resistant to heat and chemicals.

The inherent chemical resistance of vulcanized natural rubber has been known for many years. While this property was utilized for mechanical goods, such as hose, tubing and gaskets prior to 1925, natural rubber lacked general utility for chemical resistant construction because no satisfactory method of bonding rubber to steel was known at that time. The first satisfactory adhesive for this purpose was prepared by Fisher, who heated natural rubber in the presence of organic sulfonic acids to form products called thermoprenes, which are essentially polycyclo rubbers.

As indicated by a typical structural formula, thermoprenes have chemical properties similar to natural rubber. However, they are not vulcanizable and tend to cold flow. They do not possess rubbery properties and resemble shellac rather than natural rubber. Thermoprenes and more recently developed adhesives have been used successfully to bond sheet rubber to steel in a large number of commercial installations.

Rubber has been used as rubber latex, mixtures of rubber latex and hydraulic cement, as solutions and as a soft and hard vulcanized rubber. The last two constitute the major applications of natural rubber in chemical process equipment where it is utilized as tank linings, gaskets, hose, tubing and for expansion joints.

### Butyl Rubber

One of the principal deficiencies of polyisobutylene is its lack of resistance to heat. This deficiency has been overcome in part by Thomas, Lightbown, Sparks, Frolich and Murphee, who copolymerized isobutylene with isoprene to obtain a product called butyl rubber which may be subsequently vulcanized. When considering the structure formula for butyl rubber, it should be remembered that the isoprene groups in the molecule constitute only one or two percent of the entire structure, the remainder being polyisobutylene groups. With the exception of its greater resistance to flow, vulcanized butyl rubber has essentially the same chemical resistance as polyisobutylene.

### Chlorosulfonated Polyethylene

As indicated by its formula, chlorosulfonated polyethylene is a product obtained by reacting polyethylene with chlorine and sulfur dioxide. This derivative has many of the properties of polyethylene but is considerably more polar. Thus, it will adhere more readily to metallic surfaces and has superior heat resistance. Because of the presence of the active groups, the product can be cured with basic compounds, such as litharge, to produce a rubber-like material that is resistant to most solvents, salts, acids, alkalies and oxidizing agents at temperatures up to 212 degrees F. Because this product is new, little background data based on experience is available but chlorosulfonated polyethylene does show promise of supplying a long-wanted need.

### Rubber Hydrochloride

Rubber hydrochloride may be represented best by the structural formula shown. It is seldom used as a chemical resistant material except inadvertently in rubber lined equipment exposed to hydrochloric acid. As might be expected, from the formula, rubber hydrochloride is more soluble in organic solvents and is much less elastic than natural rubber.

### Chlorinated Rubber

Chlorinated rubber was first made by Roxburgh in 1801 but was not produced commercially until 1859 when Englehard and Day and Havemann independently patented processes for making this rubber derivative. Chlorinated rubber was used first as a protective coating in 1915 and predates most of the other commercial protective synthetic coatings.

Chlorinated rubber is a non-elastic product which is soluble in a wide variety of organic solvents. As indicated by its structural formula, the resistance of chlorinated rubber to non-oxidizing salts, alkalies and acids is similar to natural rubber. Because it contains fewer double bonds, chlorinated rubber is more resistant to oxidizing agents than natural rubber.

The principal use of chlorinated rubber is for protective coatings and adhesives. Attempts to use chlorinated rubber for extruded pipe or molded plastics have not been promising because of its inherently poor heat stability.

Isomerized or cyclized rubber has been used as an adhesive and a protective coating but is being replaced to a large extent by styrene-butadiene copolymers.

### Styrene Rubber

Styrene rubber sometimes called Buna S or GR-S is the most widely used synthetic rubber. However, its application in chemical resistant construction is considerably less than that of natural rubber, primarily because of industry's greater familiarity with the latter.

A quick study of its structural formula will indicate that styrene rubber is quite similar to natural rubber in its resistance to alkalies, acids, salts and solvents. Its physical properties are somewhat inferior to those of natural rubber but this deficiency is being overcome through improved manufacturing and compounding techniques.

### Acrylonitrile Rubber

Acrylonitrile rubber, sometimes called Buna N or GR-A is used occasionally in chemical resistant construction when oil resistance is an essential requirement. It is being used to some extent as a blending agent for low impact polymers, such as polyvinyl chloride and styrene-acrylonitrile copolymers. Since it contains cyano groups, it is less resistant to alkalies than natural and synthetic rubber but has good resistance to acids and salts.

### Neoprene

Neoprene was produced first from vinyl acetylene by Carothers in 1931. Vinyl acetylene and related compounds had been synthethized previously from acetylene by Nieuwland. As indicated by its structural formula, neoprene or polychloroprene is related chemically to natural rubber. The substitution of chlorine for a methyl group produces superior resistance to vegetable and mineral oils, aging and high temperature. Hydrochloric acid and related compounds which react with natural rubber actually permeate neoprene and hence, neoprene linings are not recommended for use in the presence of hydrochloric or hydrofluoric acids. When cured with litharge and similar curing agents, neoprene is resistant to all other non-oxidizing acids, salts and alkalies.

Neoprene is available in the form of hose and other mechanical goods, sheet linings, putty-like cements, protective coatings and aqueous dispersions. Sheet neoprene is not used as widely as natural rubber in chemical resistant construction but is recommended for specialized uses when oil resistance is required. Because neoprene yields solutions with high solids content, it finds considerable use as a quality protective coating in chemical industry. These coatings can be cured at ordinary temperature producing a highly elastic film that will not flow even at the temperature of boiling water.

### Polysulfide Rubber

Polysulfide rubbers were developed by Patrick in 1932 by the condensation of sodium polysulfide and dichloro compounds, such as ethylene dichloride. These products are somewhat rubbery and have excellent resistance to solvents. While somewhat odoriferous, they have good resistance to salts and non-oxidizing acids and fair resistance to alkalies.

Polysulfide rubbers are available as liquids which may be converted to solids at room temperature, as aqueous dispersions and as solids which may be flame-sprayed or applied as sheets. The liquid polymers are used as solvent-resistant caulking compositions. The solid is used as a plasticizer for sulfur cements, for solvent resistant mechanical goods and as a flame-sprayed coating for marine equipment. Aqueous dispersions have been used as solvent-resistant tank linings.

### Cellulose Esters and Ethers

As apparent from its structural formula, cellulose is a polyglucoside; the dimer cellobiose being the simplest unit. Starch is also a polymer of glucose but its simplest dimer unit is maltose, an isomer of cellobiose. Cellulose in its natural form has been used for chemical resistant construction for many years. Wood is resistant to most salts and solvents but is attacked slowly by acids and alkalies. The rate of attack is governed to a large extent by the type of wood used.

Cellulose nitrate, which was first prepared by Schönbein in 1845 and plasticized with camphor by Hyatt in 1867, is resistant to salts and some acids but is attacked by alkalies. Cellulose nitrate is soluble in many solvents and is highly inflammable. It is used widely for rapid drying coatings but does not find much use in corrosion resistant construction.

Cellulose acetate was first prepared by Schutzenberger and Harden in 1865 and while its solutions in ester solvents were used as airplane dopes during World War I, it was not available commercially as a plastic until 20 years later. Because of its inherent toughness and fair resistance to flame, cellulose acetate molded and extruded parts have been used industrially although not extensively as chemical resistant materials.

Since cellulose acetate butyrate and other mixed esters can be more readily plasticized and have better water resistance than cellulose acetate, they have been used as pipe and tubing for mild service in the chemical industry. Cellulose acetate butyrate, like cellulose acetate, is resistant to salt and petroleum solvents but is not recommended for use in acid and alkaline service. Extruded cellulose acetate butyrate pipe has been used quite extensively in the petro-

leum industry and to some extent for transporting water and gas.

Methyl cellulose was first prepared in the laboratory by Suida in 1905 and in commercial quantities by Dreyfus several years later. Because of its lack of resistance to water, it is not used in chemical resistant construction. Most commercial applications of methyl cellulose are based on its solubility in water.

Ethyl cellulose is more water resistant than methyl cellulose. It is not attacked by corrosive salts and finds some use as a hot dip coating for protecting metal objects. Carboxymethyl cellulose is too water soluble to merit consideration as a chemical resistant plastic.

### Polyesters

Saturated polyesters were first studied in 1929 by Carothers and Arvin, who formed plastic materials by reacting glycols with dibasic acids. For example, ethylenesuccinate was obtained from succinic acid and ethylene glycol.

The simplest type of commercial polyesters are the so-called alkyds based on modifications of Smith's original condensation of glycerol and phthalic anhydride described in an article published about 1900 and Kienle's subsequent incorporation of unsaturated fatty acids, such as oleic acid to produce curable films. This type of polyester is used widely for decorative coatings but finds little use in corrosion resistant construction.

Unsaturated polyester plastics, which are of much greater interest to corrosion engineers than alkyds, are based on a more recent modification by Rust. He substituted an unsaturated anhydride, such as maleic anhydride for phthalic anhydride and copolymerized the resulting unsaturated polyester with styrene. Such products are now used widely when reinforced with glass fibers. These polyesters have good resistance to non-oxidizing acids and corrosive salts but are not suitable for use with alkaline solutions or oxidizing agents. Reinforced polyesters have been used for pipe, ductwork and self-supporting tanks. Polyesters differ from most of the plastics discussed previously because they are thermosetting and thus, when cured, cannot be resoftened by heat and pressure. (Other thermosetting plastics are phenolic, urea, melamine and furan plastics.)

### Urea and Melamine Resins

Resinous products prepared by the condensation of urea and formaldehyde using the techniques developed by John in 1920 have been available commercially since 1928. Products with better resistance to heat were developed by Talbot some ten years later by using melamine in place of urea. Both products are resistant to heat, some solvents and most salts. They are not used extensively as chemical resistant materials.

### Phenolic Resins

As previously stated, phenolic resins were developed commercially by Baekeland in 1908 and are essentially alkaline or acidic condensation products of phenol and formaldehyde. A dyhydric phenol, resorcinol or a substituted phenol, such as cashew nut oil may be used in place of phenol to form faster setting, more adhesive resins and more flexible products respectively. Furfural also may be used in place of formaldehyde.

Phenolic resins contain free hydroxyl groups which are attacked by alkalies. However, they have excellent resistance to salts, many solvents and non-oxidizing acids. Phenolic resins are used as heat-cured coatings, molding powders, casting resins and cements.

### Epoxy Resins

Reaction products of bisphenol and epichlorohydrin called epoxy resins do not contain free phenolic groups and, hence, have good alkaline resistance. They are excellent adhesives and are resistant to salts, many solvents and non-oxidizing acids. Epoxy resins are used as room temperature catalyzed coatings and cements and heat-cured coatings, castings and cements.

### Furans

Furfural and furfuryl alcohol can be polymerized by acids to produce infusible products which have excellent resistance to chemicals. Proprietary cements, pipe and chemical resistant structures based on filled resins from furfuryl alcohol and furfural have been available commercially for some time. These products, as well as those prepared from acetone and furfural, are all grouped under the general generic term of furans. Thus, in the absence of additional classification data, only the experienced chemist can differentiate among these products. Fortunately for the corrosion engineer all furans are resistant to heat, alkalies, salts, solvents and non-oxidizing acids. So-called furan cements are attacked by chlorine, sodium hypochlorite, nitric acid, chromic acid, concentrated sulfuric acid and other oxidizing agents.

### Summary

While there is no substitute for past experience and on-stream plant testing programs, an understanding of the molecular structure of plastics will aid immeasurably in the selection of nonmetallic materials of construction. The proper use of basic plastics knowledge should prevent misinterpretation of test results. If actual tests are completely contrary to predictions for a specific product, application methods and the possible presence of non-resistant fillers, etc. should be investigated. Obviously, the information contained in this chapter cannot be used intelligently unless the generic nature of the plastic material under consideration is known.

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# Topic of the Month

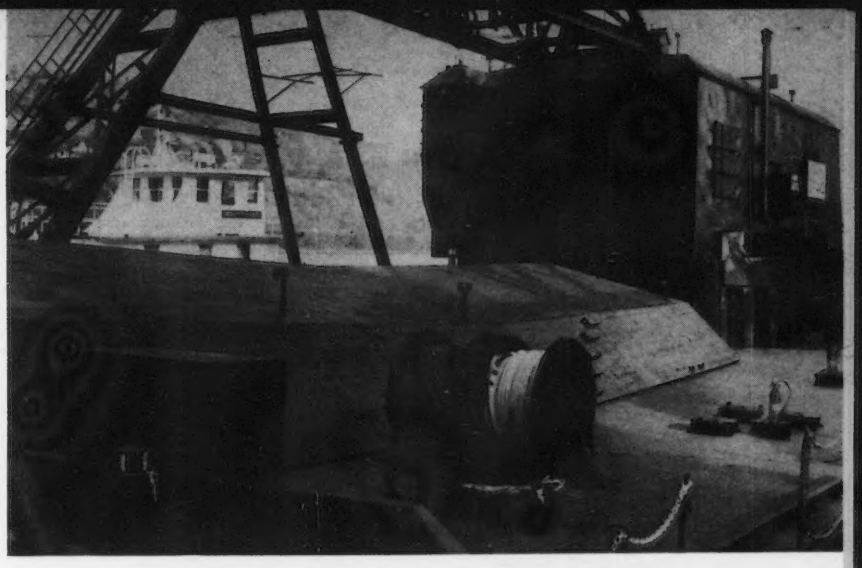

Figure 1—View of 100-ton floating crane during final preservation procedures. Cable reels are being protected by strippable coating. Inboard reel has had first coating and outboard reel is covered with contour conforming wrap preparatory to spraying. Note metal cover on capstan control in lower left hand corner.

# Preservation of Floating Cranes For Government Stockpiling

By R. RAYMOND EWART*

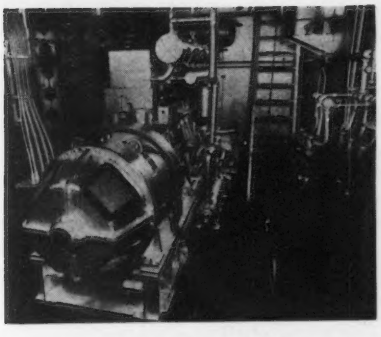

Figure 2—Starboard main Diesel generator unit partially processed. Carbon monoxide fire extinguishers at right may be actuated from main deck and although preserved are kept fully charged and operative.

PRESERVATION of critical materials for stockpiling is an important requirement of numerous government purchases. An example of this is the major construction and preservation project in which Dravo Corporation of Pittsburgh is presently engaged. This program, involving seven 100-ton capacity floating cranes and twenty-three 60-ton units, requires each critical component to be protected for an "unspecified" period of storage.

Unprotected metal parts, such as crane rollers, swinger gear and guide rails subject to corrosion and rust must be thoroughly cleaned with a specified solvent and then given a liberal coating of a preservative. Items normally covered by sheet metal guards or obstructed by machinery assemblies are exposed and components thus exposed are similarly treated. No external or critical interior part of any unit that constitutes a working part of the crane is neglected. Couplings, reduction gears, hoist machinery, engines, compressors, controls and all other vital parts of the assembly come under the attention of the preservation crew and are treated in accordance with their particular specification.

Tanks and piping are important in many of the systems and must either be flushed or coated internally to withstand atmospheric attack which may destroy an unprotected unit in a matter of weeks. In some instances, such as the cooling water jackets of the Diesel engines or the ballast manifold on the 100-ton cranes, an anti-freeze solution composed of 60 percent ethylene glycol, 40 percent water and 5 percent of soluble corrosion preventive oil is used. This solution, in addition to stopping of rust or corrosion, serves to protect the equipment from freezing. Each tank and its piping is sealed against air, water or detrimental vapors.

Where surface coatings are not feasible, as in the case of electrical motors or controls, a different method of preservation is required. Motor brushes are lifted free of the commutator and a section of barrier material is put beneath each. Provision is made also for meggering tests by cutting suitable slots in the barrier at a location which will not interfere with the protective wrap. The motor itself is then sealed to prevent the entrance of liquid water, after which the leads are disconnected, sealed and tagged with identifying non-ferrous plates.

Bearings and shafting for motors and generators are preserved in the same way as those of other machinery. Sealing the motor leads and entrance wires is of major importance because moisture entering any of the unprotected ends can completely destroy the wire. All electrical fixtures are made moisture-vapor proof either through the use of rubber grommets or by means of approved barrier wraps. Entrances into controls, housings or various structures are sealed by glands capable of barring entrance to both liquid water and vapor. Water-tight fixtures are used invariably but because these are only water-tight they must be sealed further against vapors.

Electrical controls, one of the most important and undoubtedly the most easily affected assemblies, require individual enclosure in sturdy barrier packages. These packages are made up of a frame structure erected around the unit (or the box of the control itself if it is sufficient) which is covered with a foil-type water-and-vapor-proof barrier. This barrier is heat sealed at all seams, which, since it has a very low moisture transmission rate, effectively seals the unit. To protect this barrier and to further reduce the possibility moisture will gain access to the enclosed assemblies, the entire unit is sprayed with a strippable coating of approximately 30 mils' thickness. After this, a quantity of activated desiccant is enclosed in each package.

Sturdy protective covers are installed to prevent damage to the coatings on all exposed critical assemblies. These covers also give valuable protection against the environment during the storage period.

Bracings and guard timbers are placed at strategic points to compensate for flexing of the structures during transit and to act as buffers for critical electrical components in the event of a collision. Wherever a setting may be disturbed, as is the case with vibration dampers under Diesel engines, retaining plates are added to maintain original adjustment.

* Engineering Works Division, Dravo Corp., Pittsburgh, Pa.

# NACE News

# Three New NACE Sections Are Being Organized

## *Rocky Mountain Group at Denver Presents Petition*

South Central Region's board of trustees has been petitioned by a group of NACE members at Denver for a section charter. The new section is to be called the Rocky Mountain Section. At a December 11 dinner meeting 16 NACE members adopted rules and regulations for the section and forwarded them for approval.

The section is to include members living in Colorado, New Mexico and western Kansas.

Temporary officers elected were: Wayne E. Schultz, Dearborn Chemical Company, Denver, chairman; Karl S. Hagius, Colorado Interstate Gas Co., Colorado Springs, Colo., vice-chairman and John F. Fugazzi, Public Service Company of Colorado, Denver, secretary-treasurer.

## New England Section Hears Talk About Cathodic Protection

Cathodic Protection of Metallic Structures was the topic of a talk December 2 before members of Southern New England Section by Hilary Humble, Dow Chemical Co., Midland, Mich. Mr. Humble first explained the general concept of cathodic protection and then detailed some applications including domestic hot water tanks, pipe lines, ships and heat exchangers. There was considerable discussion.

The first of a series of educational films was shown. It dealt with the electron and its role in electrical conduction.

Results of the election of officers was given. Elected were Arthur W. Tracy, American Brass Co., Waterbury, Conn., chairman; F. M. Barry, Scovill Mfg. Co., Waterbury, vice-chairman; L. M. Rasmussen, Manning, Maxwell & Moore, Inc., Stratford, Conn., secretary-treasurer.

## Indian Institute to Meet

The Seventh Annual General Meeting of the Indian Institute of Metals will be held February 7-8, 1954. A technical session and other events will be featured. Members of NACE in India at the time are invited to attend the sessions.

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Requests for reprints of technical or other material published in CORROSION should be addressed to NACE's Central Office, 1061 M & M Bldg., Houston 2, Texas.

## NACE MEETINGS CALENDAR

**Jan.**

4—North Texas Section. R. R. Crowdus, Dallas Power & Light Co., Cooling Water Problems.

7—Pittsburgh Section.

11—Greater Kansas City Section. Discussion, Cathodic Protection Design and Application, L. F. Heverly, chairman. American Legion World War II Memorial, Kansas City.

12—Houston Section. Panel on Off-shore Oil Corrosion, Frank Dial, Pure Oil Co., Mouston, moderator. Film on off-shore oil fire will be shown.

14—Detroit Section.

19—Cleveland Section. Allerton Hotel. Joint meeting with The Electrochemical Society. Film on Filiform Corrosion, by Sherwin-Williams Paint Co. to be shown.

19—Shreveport Section. Modern Methods of Pipe Coating, Robert L. Bullock, Interstate Oil Pipe Line Company, Shreveport.

21—Greater St. Louis Section. Weld Seam Corrosion and Its Control, A. J. Liebman, Pitmar Centrifugal Machine Corp.

26—Southwestern Ohio. Round table discussion on corrosion.

**Feb.**

1—Greater Kansas City Section. Construction and Application of the Magnetic Amplifier Rectifier, Daniel R. Werner. American Legion World War II Memorial, Kansas City.

3—Greater Boston Section. Protective Coatings, Lou Bake, E. I. du Pont de Nemours & Co., Inc. Wilmington, Del. Hotel Beaconsfield, Boston.

8—Greater St. Louis Section. Motion picture and discussion on the use of Fiberglas pipe wrap, John B. Roadhouse, Owens-Corning Fiberglas Corp., York Hotel.

9—Houston Section. General Aspects of Metallurgy in Corrosive Environments. Coffee speaker, Val Gene McCoy, "Public Relations Is Everybody's Business."

16—Cleveland Section. Management's Attitude Toward Corrosion Control, Les Cannon.

25—Detroit Section.

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Additional copies of CORROSION are available at 50c each to NACE members and $1 each to non-members.

## *Two Additions Bring to 10 Number Organized in N.E.*

Two new sections have been formed in North East Region, National Association of Corrosion Engineers, bringing to ten the number in the region and to 38 the number in the United States and Canada. Petitions for the Gennessee Valley and the Schenectady-Albany-Troy Sections were approved by the region's board of trustees at a meeting in Philadelphia December 3.

Orson J. Britton, The Pfaudler Co., Rochester, N. Y. led in the organization of the Gennessee Valley Section and Arthur C. Mengel, American Locomotive Co., Schenectady, N. Y. in the Schenectady-Albany-Troy Section.

## Metropolitan Section To Install Officers At January 20 Meeting

Installation of new officers, a joint meeting with the Society of Naval Architects and Marine Engineers and a technical talk on A Shipbuilder Looks at Corrosion are to be highlights of the January 20 meeting of the Metropolitan New York Section.

New section officers to be installed are: M. Bermann, Brooklyn Union Gas Co., chairman; F. J. LeFebvre, Electro Rust-Proofing Corp., vice-chairman and R. H. Lucke, Esso Standard Oil Co., Linden, N. J., secretary-treasurer.

Technical speaker will be Paul Ffield, who will discuss corrosion as it occurs on the hulls, in the cargo storage tanks and in piping throughout ships. Mr. Ffield is superintendent of development and research, Central Technical Dept., Shipbuilding Div., Bethlehem Steel Co. The January meeting will be held at the Chemist's Club, 52 E. 41st St., New York, N. Y.

Eighty members and guests attending the December 2 Section meeting held at the Chemists' Club heard T. J. Maitland, The American Telephone and Telegraph Co., speak on "Corrosion Control of Lead Sheath Cables." The talk included a discussion of the various types of corrosion affecting lead sheath cables, measurements and testing, techniques used to detect conditions conducive to corrosion and mitigative measures taken including use of non-metallic outer sheaths and cathodic protection. The subject of coordination of cathodic protection currents with interference currents in underground structures was considered also.

# Agenda of Berkeley Marine Corrosion Conference Given

Agenda of the University of California, Berkeley Conference on Marine Corrosion Problems, February 8-9 has been prepared. Topics to be covered include environmental and biological factors, selection of materials, marine paints, cathodic protection, tanker corrosion, corrosion in laid-up ships and a panel discussion of special topics. Registration fee of $10 is payable to University of California, Berkeley, attention I. Cornet, Assoc. Prof. Mechanical Engineering, UCAL, Berkeley. The conference is sponsored by the university and Western Region, National Association of Corrosion Engineers.

The schedule is as follows:

**Monday, February 8**

8-8:30 am—Registration.
8:30-10 am—Environmental Factors in Marine Corrosion, F. L. LaQue, Corrosion Engineering Section, International Nickel Co., Inc., New York.
10:15-11:45 am—Biological Factors in Marine Corrosion, Prof. Claude ZoBell, Dept. Marine Microbiology, Scripps Institute of Oceanography.
1-3 pm—Selection of Materials for Marine Service, F. L. LaQue.
3:15-5:15 pm—Marine paints. Speaker to be named.

**Tuesday, February 9**

8:30-11:45 am—Cathodic Protection for Marine Service Piling, Docks, Ships, Drilling Rigs, Wells, Offshore Pipe Lines by H. A. Humble, Magnesium Dept., Dow Chemical Co., Midland, Mich. and James F. Hirshfeld, The Hinchman Corp., Detroit.
1:30-3 pm—Tanker Corrosion, H. A. Pray, Battelle Memorial Institute, Columbus, Ohio.
1:30-3 pm—Corrosion in Laid-Up Ships, Allen L. Alexander, Protective Coatings Branch, Naval Research Laboratory.
3:15-4:15 pm—Panel Discussion of Special Topics, all speakers on panel.

## Protective Coatings Is Boston Section's Topic

Greater Boston Section will hear Lou Bake of E. I. du Pont de Nemours & Co., Inc. speak on Protective Coatings at the section meeting to be held February 3.

At the December 2, 1953 dinner meeting, Northeast Regional Chairman George E. Best joined 55 members and guests of the section to hear Dr. F. N. Alquist of Dow Chemical Company's Organic Research Div., Midland, Mich. speak on The Use of Inhibitors in Water Treatment. Interest in the subject was evidenced by the questions and comments during the discussion period which followed. Dr. Alquist is chairman of NACE Technical Committee 13.

Preceding Dr. Alquist's talk, a sound film in color, A Preliminary Investigation of Fretting Corrosion was presented as a special feature with added commentary by Milton Stern of the Corrosion Laboratory of the Massachusetts Institute of Technology.

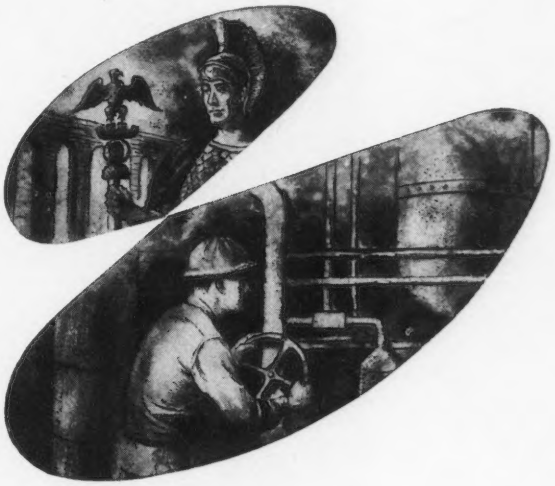
## Kansas City Section Hears Talk on Anodes

Uses of carbon and graphite anodes with impressed currents were discussed at the November 3 dinner meeting of Greater Kansas City Section. Ten members and 5 guests were present at American Legion World War II Memorial to hear J. P. Oliver of National Carbon Company tell about applications with these anodes in fresh and salt water and swampy areas as well as other types of installations.

Mr. Oliver emphasized the need for the presence of oxygen to assure satisfactory anode operation. Although the theoretical capacity of graphite was 4050 ampere hours a pound, he said under some conditions this was far exceeded. Many questions were answered about the uses and manufacture of carbon and graphite anodes.

At the December 7 meeting L. F. Heverly, Great Lakes Pipe Line Co., Kansas City, Kan. was scheduled to speak on corrosion of dissimilar metals.

The January 11 meeting will center around a round table discussion on cathodic protection design and application with Mr. Heverly as chairman and the February 1 meeting will hear Daniel R. Werner, American Telephone and Telegraph Co., Kansas City speak on Construction and Application of the Magnetic Amplifier Rectifier. All meetings are at American Legion Memorial.

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# 5-Day Corrosion Sessions Held at Los Angeles

## Short Course, Regional Meetings Are Popular

Western Region's 5-day corrosion control activity at Los Angeles November 16-20 was participated in by 98 enrollees at the short course and 164 registrants for the regional meeting. Officers of Western Region credited committees that planned and arranged the conference for its success and the committee consisting of P. W. Hill of Signal Oil and Gas Co., N. K. Senatoroff, of Southern Counties Gas Co. and J. C. Dillon of University of California at Los Angeles for the success of the short course.

The short course on cathodic protection, held during the first three days of the week, included lectures by R. M. Wainwright, University of Illinois, Urbana, on Economics of Cathodic Protection; H. J. Keeling, Southern Counties Gas Co., on Corrosion Circuit Theory; R. E. Hall, Union Oil Co., Field Testing Practices; E. P. Doremus, Cathodic Protection Service, on Design and Application of Cathodic Protection. Other speakers included W. F. Seyer, UCLA; J. F. Hirshfeld, Hinchman Corp.; H. N. Hayward, University of Illinois; W. M. Schilling and R. H. Kerr, Southern Counties Gas Co.

### Anderson Speaks

H. H. Anderson, vice-president and general manager of Trans-Mountain Oil Pipe Line Co., Vancouver spoke on Selling Management on Corrosion Control, which also had been the Western Region theme for 1953. Mr. Anderson also presented the color film Piping Oil Across the Rockies, depicting the difficulties encountered in building 718 miles of pipe line from Edmonton to Vancouver.

F. H. Hough, Southern Counties Gas Co., Howard D. Segool, Kendall Company and Mark F. Adams, State College of Washington presented papers during a symposium on pipe line problems. Oil industry corrosion problems were covered in papers by R. S. Crog, Union Oil Co.; G. E. Purdy, Tretolite Co. and B. B. Morton, The International Nickel Co., Inc.

The corrosion problems peculiar to the aircraft industry were discussed by J. S. Farra, J. L. Waisman and R. N. Hooker, all of Douglas Aircraft Company and J. V. Long of Solar Aircraft Co.

### Technical Committees Meet

Thursday morning meetings were held by Technical Practices Subcommittee 1-A on Corrosion of Oil and Gas Well Equipment, Frank Davie, chairman and TP 6-L on Asphalt Type Underground Protective Coatings, R. J. Schmidt, chairman.

A fellowship hour and buffet sponsored by area manufacturers was held. Congratulations for the enjoyable event were given K. T. Vangnes, The Vanode Co. and W. G. McSparran, Aluminum Company of America.

### National Meeting Sought

A resolution at the general business meeting was introduced by L. L. Whiteneck, regional director and unanimously carried asking that the national meeting of the National Association of Corrosion Engineers be held in a city in Western Region in 1957 or 1958.

Reports from Fred McConnell, Koppers Co., on section membership activity were heard and a plan for regional educational activity was outlined by Prof. Cornet.

Results of the election of regional officers were announced.

**WESTERN REGION 1953 fall meeting: Top, Some of the NACE regional and sectional officers present, left to right, Robert H. Kerr, 1954 regional chairman; E. H. Grizzard, 1953 regional chairman; Austin S. Joy, 1953 regional vice-chairman; A. B. Campbell, NACE executive secretary; Harry R. Brough, Salt Lake City Section chairman. Middle: Western Region Section Officers, left to right, Harry R. Brough; S. J. Artese and S. K. Gally, Los Angeles Section chairman and vice-chairman; Lynn E. Magoffin, Dallas D. Raasch and D. P. Armbruster, San Diego Section chairman, treasurer and vice-chairman; Bottom: 1953 Fall Conference committeemen: K. T. Vangsnes, hospitality chairman; Albert G. Zima, membership co-chairman; Joseph W. Coffey, facility arrangement co-chairman; Fred M. McConnell, membership chairman; Hugh F. Flynn, registration chairman; David J. Collyer, Jr., publicity co-chairman; Dean E. Stephan, facility arrangement chairman. Other committeemen were absent.**

## J. F. Wilkes Heard

Fourteen members and 11 guests of Greater St. Louis Section heard J. F. Wilkes of Dearborn Chemical Company talk on Corrosion Problems in Ion Exchange Systems November 9. Mr. Wilkes is director of research and development of Dearborn.

## Cleveland Section Hears Henderson

Combating Corrosion Through Cooperative Effort in Cleveland was the topic of an address by Oliver Henderson of Ohio Bell Telephone Co., before Cleveland Section November 17. Mr. Henderson outlined the progress that has been made in cooperative efforts to control corrosion from the "dog eat dog" days to the present Committee on Electrolysis in Cleveland. The committee includes a representative from nearly every operator of underground plant in the city.

A Fellowship Hour had as hosts Messrs. H. W. Hosford, A. R. Corlett and B. Husock of Harco Corp.

## L. B. Routson

L. B. Routson, a member of the National Association of Corrosion Engineers since 1945 died during November. When he joined NACE Mr. Routson already had 21 years' experience in electrolysis mitigation work on underground cables and pneumatic tubes working for Western Union Telegraph Co. as a field engineer. His NACE application was number 408. Mr. Routson graduated from Purdue University as a bachelor of science in electrical engineering.

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Additional copies of CORROSION are available at 50c each to NACE members and $1 each to non-members.

**WESTERN REGION 1953 fall meeting speakers: Top, F. A. Hough, Vice President Southern Counties Gas Co.; Second, Mark F. Adams, Associate Chemist, Washington State Institute of Technology; Third, R. S. Crog, Research Supervisor, Union Oil Co. of California; Fourth, B. B. Morton, The International Nickel Co., Inc., and bottom, Howard D. Segool, Manager Specialized Products, Polyken Products Division, The Kendall Company.**

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Articles on corrosion science and technology are welcomed for review by the NACE Editorial Review Committee as material for publication in CORROSION's technical section.


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***By Boyd Mayes***

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That one was hard to swallow but it gave us a chance to explain our policy that's going into its twenty-seventh year without change, where service to customers is concerned.

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SOUTH EAST REGION 1953 fall meeting scenes—Top, taken during a technical session. Bottom, some of the guests during the Fellowship Hour.

# *Permian Basin Section Plans Loan Fund*

A loan fund to be set up at Odessa College and an annual trophy to a member of the National Association of Corrosion Engineers for an "Outstanding Contribution to Internal Corrosion" will be provided by Permian Basin Section NACE. These decisions were reached at a dinner meeting December 7 at Lincoln Hotel, Odessa.

The loan fund, to be of perpetuating nature and in an amount to be determined later, will be administered by the Permian Basin Section trustee and Odessa College administration officials. The exact nature of the internal corrosion award and the method of presentation will be established after discussion with the NACE Awards Committee.

Application of Scotch Nipples to Corrosion Studies, by J. P. Gould, Corona Oil Specialties and Service Co., La Canada, Cal. and a discussion of petroleum industry problems in the Middle East were followed by a paper, Economic Considerations for Internal Pipeline Corrosion Control, by L. G. Sharpe, senior corrosion engineer, Humble Pipeline Co., Houston on the technical program.

The ten members and 20 guests present also heard Lamar Sudduth announce that the 1953 Corrosion Tour Report is expected to be completed late in January or early in February.

## Rubber Linings Uses Discussed at Orange

Various uses of rubber linings in the industrial field was the technical subject for the December 3 meeting of the Sabine-Neches Section held at the Border Cafe, Orange, Texas. Herman C. Klein, B. F. Goodrich Co., Akron, Ohio was the speaker.

Mr. Klein pointed out the great progress made in rubber linings since 1924 when they were first used in the form in which they are used today. While many applications of rubber linings now are made in the field it is still necessary to have complex linings installed in the shop where an autoclave is available for vulcanizing. A lively question and answer period followed Mr. Klein's talk which was illustrated with slides. Thirty-six members and guests were present.

## Sillcox Heads ASME

Lewis K. Sillcox, The New York Air Brake Co., has been elected president of the American Society of Mechanical Engineers. Mr. Sillcox has been connected with railroad transportation since 1903.

# Corporate Representatives Honored at Houston

Houston Section devoted its December 8 meeting to pleasure and fellowship in a Christmas setting. The meeting was to honor corporate representatives and NACE "old timers" living in the Houston area. A buffet supper was served and a wassail bowl added to the festivity of the occasion.

Walter Rogers, Gulf Oil Corp., president of NACE explained in a brief talk emphasizing corporate membership, the purposes and benefits of the National Association of Corrosion Engineers. Principal function of NACE, according to Mr. Rogers, is to provide an organization where interested persons can learn from each other the best ways to prevent corrosion losses.

### Problems in Common Met

As an example of how NACE provides a common meeting ground, Mr. Rogers pointed out that the crude oil and product pipe line industries, the gas transmission industry, the water works industry, and other similar ones, all have trade associations and different corrosion groups. Their problems in common, however, are ones they cannot discuss, if they confine themselves to their separate organizations. But by cooperation in NACE, all companies having corrosion problems can work in unison.

In order to facilitate joint action by industries pursuing a common corrosion interest, the association has formed Technical Practices Committees. Each committee has been developed because of the need by members of an industry, or industries to study and discuss cooperatively, the corrosion problem common to all, with the aim of finding an economic solution.

Emphasizing that "the more you put into an endeavor the more you take out of it," NACE's president said that when a company suffering from corrosion contributes $100 to NACE for a corporate membership, it means the company is willing to bet $100 a year that the benefits of NACE to it will return more than this amount.

To point up the small comparative cost of corporate membership, he compared the estimated $600 cost to a company of maintaining one corrosion engineer in active NACE membership to the $100 the firm pays for a corporate membership.

### Many Benefits Are Cited

In conclusion, Mr. Rogers pointed out other important benefits of NACE. These were: CORROSION magazine which has increased its technical material 100 percent since it was founded; the annual conference and exhibition where technical committees and research papers are made available and the technical practices committees where each member can find a committee of interest. NACE's most profitable work can be done in these committees, according to Mr. Rogers. Additional benefits are: NACE sponsored research (present project, Stress Corrosion Cracking of Steel by Hydrogen Sulfide, sponsored by Technical Practices Committee 1-G); the Educational Committee which has sponsored many corrosion short courses in universities and has urged the creation of corrosion courses for undergraduate students; regional meetings where technical practices committees meet and where many good papers are presented and finally, section meetings where the active member gets into NACE activities himself by attending meetings, bringing up corrosion problems, taking part on corrosion panels and by presenting papers.

### Gifts Presented to "Old Tuners"

Following Mr. Rogers' talk, Mr. Kelly acting as master of ceremonies presented the "old" members small gifts. Then Mr. Kelly, a raconteur in his own right, presided over an informal session where humorous stories, some true, most not, were related.

The meeting was held at the Alabama Catering Service with 112 members and guests in attendance.

At the November 17 Section meeting, 38 student engineers from Texas A & M, the University of Texas, Rice Institute and the University of Houston met with members to hear What Managements Expect of Their Engineers, by J. R. McEntee, Service Division, The Shell Oil Co. and to listen to a technical talk by Norman Hackerman, head of the chemistry department of the University of Texas. Dr. Hackerman's subject was Fundamentals of Corrosion.

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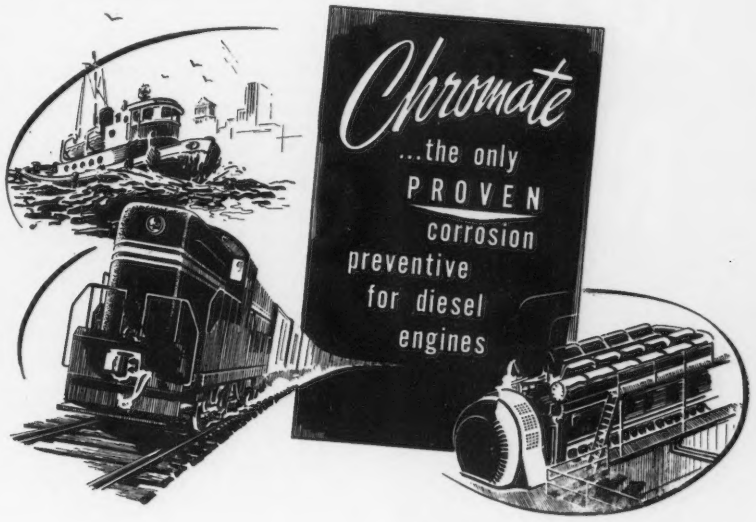


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# Washington State College to Hold 5-Day Short Course on Corrosion February 1-5

A 5-day short course in corrosion will be held on the campus of Washington State College, Pullman, February 1-5. The course will consist of a brief but intensive review of the fundamental aspects of corrosion followed by panel discussions and lectures on the application of methods to control corrosion in industry. The Division of Industrial Services of the Washington State Institute of Technology and the National Association of Corrosion Engineers are sponsoring the course jointly. M. F. Adams, of Washington State College, is program chairman.

Representative presentations to be made under each of the five major topics in the course are as follows:

Fundamentals — Physiochemical and Metallurgical Factors, H. U. Uhlig Massachusetts Institute of Technology.

Practical Aspects—Corrosion Testing and Evaluation, F. L. LaQue, Chief, Corrosion Engineering Section, International Nickel Co.

Corrosion Mitigation—Cathodic Protection and Inhibitors, G. H. Rohrback, Consulting corrosion engineer.

Environment—Process Industry, Aaron Wachter, Chief Corrosion Research, Shell Development Co.

Additional information on the course may be obtained from Prof. W. B. Parker, Director, Division of Industrial Services, State College of Washington, Pullman.

## Vancouver Section Sees Inco Motion Picture

Election of officers for 1954 and a showing of "Corrosion in Action," the International Nickel Company, Inc. film followed by a discussion period formed the heart of the Vancouver Section meeting November 26 at the Canadian Forestry Association Hall in Vancouver.

Officers elected were: F. M. Cazalet, British Columbia Electric Co., Ltd., chairman; G. E. Maynard, G. S. Eldridge & Co., Ltd., vice-chairman; B. H. Levelton, British Columbia Research Council, secretary; Frank G. Mitchell, Wilkinson Co., Ltd., treasurer; B. Robinson, Shell Oil Co., membership chairman, all of Vancouver; and J. A. H. Carson, Pacific Naval Laboratory, Esquimalt, B. C., section trustee.

During the discussion period, one question concerned the feasibility of cathodically protecting supporting racks used in a hydrochloric acid pickling bath. It was pointed out that this type of protection has not been tried in an acidic medium and that the material being pickled would be protected cathodically. At present the racks are made of mild steel and the operator has found a paint which resists corrosion satisfactorily, but which is broken off by physical abrasion.

Another question concerned the possibility of protecting lead cable sheaths by pulling ribbon magnesium through an empty conduit. It was decided that it would be difficult to obtain good anode-to-earth contact. The conduit is partially full of water but in parts may be completely dry.

Case histories of erosion-corrosion of propellers used on tug boats arose. It was claimed that unusual conditions resulted from the fact that the boat remained essentially at a standstill while the propeller was rotating at full speed. The occurrence of a critical tip velocity for incipient erosion was discussed.

## Merits of Plastic Tapes Is Topic at Pittsburgh

Relative merits of polyvinyl chloride, polyethylene and synthetic rubber tapes were discussed by Norman P. Peifer, Manufacturers Light and Heat Co., of Pittsburgh at a November 17 dinner meeting of Chicago Section. Ninety-six members and guests were present to hear Mr. Peifer's talk titled "A Consumer's Report on Vinyl Coatings," and to participate in the informal discussion following his talk.

Mr. Peifer discussed wrapping pipe line joints and small distribution lines in city systems where the cost of the wrappings may be justified. He focused attention on the advantages, disadvantages, testing methods and future uses of polyvinyl chloride tapes.

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## Searer Addresses Joint Meeting at Niagara Falls

Jay C. Searer, Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y., addressed 35 members and 5 guests at a joint Western New York Section—Electrochemical Society meeting November 12. The dinner meeting was held at Niagara Falls.

Dr. Searer told his listeners about the amazingly rapid growth of the plastics industry, emphasizing that while no universal solution to corrosion problems was immediately visible, many solutions for specific problems are available. Engineers present were urged to discuss their corrosion problems with manufacturers, fabricators and applicators of plastics and gain the benefit of their experience. Many questions were asked and answered and exhibits of finished plastic products examined.

F. L. LaQue of International Nickel Co., Inc., is scheduled to address the next meeting of the section.

## NBS Sorter Improved

An improved machine for sorting physical objects into a large number of categories through the use of an electromechanical system for separating items has been developed by the National Bureau of Standards. The device was built to sort punched cards, but according to the bureau, the principle is applicable to sorting such other objects as mail, electrical and mechanical components and even farm produce as well as checks, invoices and other papers.

## WHO'S WHO ON KANSAS CITY PROGRAM

Peabody

Fisher

Bullock

Uhlig

**A. W. Peabody**—Electrical engineer with Ebasco Services, Inc., New York City, he is a graduate of the University of Maine. Since 1939, with the exception of service in the Signal Corps, he has been occupied with corrosion prevention and design of cathodic protection equipment for underground use. He is co-chairman of the Pipe Line Coating Symposium.

**A. Orman Fisher**—Corrosion engineer for the Merrimac Division, Monsanto Chemical Co., he holds a BS in chemical engineering from Northeastern University, Boston, Mass. He has been with Merrimac Research Department since 1944 and has specialized in corrosion since 1949. He is currently vice-chairman of Boston Section NACE and is a member of ACS and ASM also. He is co-chairman of the General Corrosion Problems Round Table at the Kansas City Conference.

**Robert L. Bullock**—Since 1935 with affiliates of Standard Oil Co. of New Jersey, he is now corrosion engineer with Interstate Oil Pipe Line Company, Shreveport, La. Mr. Bullock, chairman of the technical program committee for the 1952 conference, organized Tulsa Section and has been active in the association's technical committees and otherwise. He is co-chairman of the Pipe Line Group Discussion to be held during the Tenth Annual Conference of NACE at Kansas City.

**Herbert H. Uhlig**—Dr. Uhlig has written so many articles on and been so active in corrosion work for so many years it is futile to attempt to give a resume of his activities. He is currently in charge of the corrosion laboratory at Massachusetts Institute of Technology. He has long been active in NACE affairs and is sought after as a lecturer on corrosion science. He was recipient of the NACE Whitney Award in 1951. He is co-chairman of the Cost of Corrosion Symposium at Kansas City in March.

## *Two Papers Added*

Two papers have been added to the Cost of Corrosion Symposium to be given during the NACE Tenth Annual Conference and Exhibition at Kansas City in March. The additions bring to three the number scheduled for the symposium.

They are: "Lessen Atmospheric Corrosion Costs by Testing Programs," by C. P. Larrabee, United States Steel Corp., Vandegrift, Pa., and a paper as yet untitled by Aaron Wachter, Shell Development Corp., Emeryville, Cal.

## Roll Named Chairman of North East Region

Kempton H. Roll, Lead Industries Association, New York City has been elected chairman of North East Region, National Association of Corrosion Engineers. Also elected to serve during 1954 were Edward G. Brink, American Viscose Corp., Marcus Hook, Pa., vice-chairman and Edwin J. Titsworth, Koppers Co., Inc., Boston, Mass. secretary-treasurer.

George E. Best, Mutual Chemical Co., of America, Baltimore, Md. was elected to a three-year term on the NACE board of directors, effective with the last day of the 1954 NACE Conference at Kansas City. He succeeds L. B. Donovan, Consolidated Edison Co. of New York, Inc., New York City.

## Lapel Pins to Cost $10

NACE lapel pins, which have been sold for $7 each now will cost $10, the NACE board of directors ruled at its meeting in Kansas City December 4-5, 1953.

## *112 Kansas City Exhibit Booths Have Been Taken*

Eighteen companies have taken booths in addition to those listed in December, 1953, CORROSION. This brings to 112 booths the number sold, leaving 29 unassigned. O. E. Murrey, NACE Exhibits Committee chairman for the Kansas City Conference and Exhibition said he expects the remaining booths to be taken before the end of 1953. So far 73 companies are scheduled to exhibit their products and services.

Companies that have taken booths since the publication of the list in December are:

Ampco Metal, Inc.
A. M. Byers Co.
Carboline Company
Cathodic Equipment Co.
M. J. Crose Mfg. Co., Inc.
Deady Chemical Co.
Gray Company, Inc.
Harco Corp.
Hill, Hubbell & Co.,
Div. General Paint Corp.
Hills-McCanna Co.
Kansas City Pipe Coating Co.
Lukens Steel Company
Michigan Pipe Company
Midwest Pipeline Service Co.
Owens-Corning Fiberglas Corp.
Perrault Equipment Co.
Pipeline Coating & Engineering Co.
Saran Lined Pipe Co.

## Atmospheric Pollutants Symposium Cancelled

The Corrosion by Atmospheric Pollutants Symposium scheduled to be held during the NACE Tenth Annual Conference at Kansas City in March has been cancelled. It proved impossible to get papers committed for presentation on this subject.


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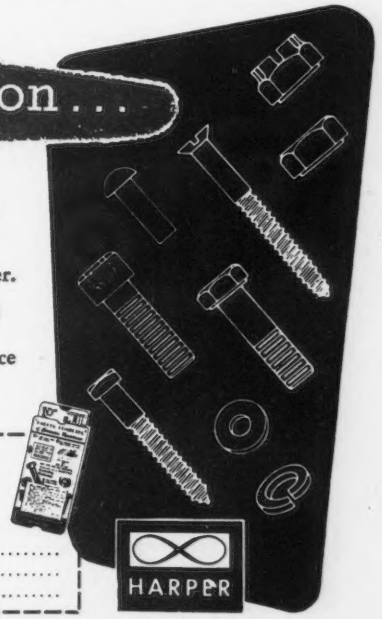

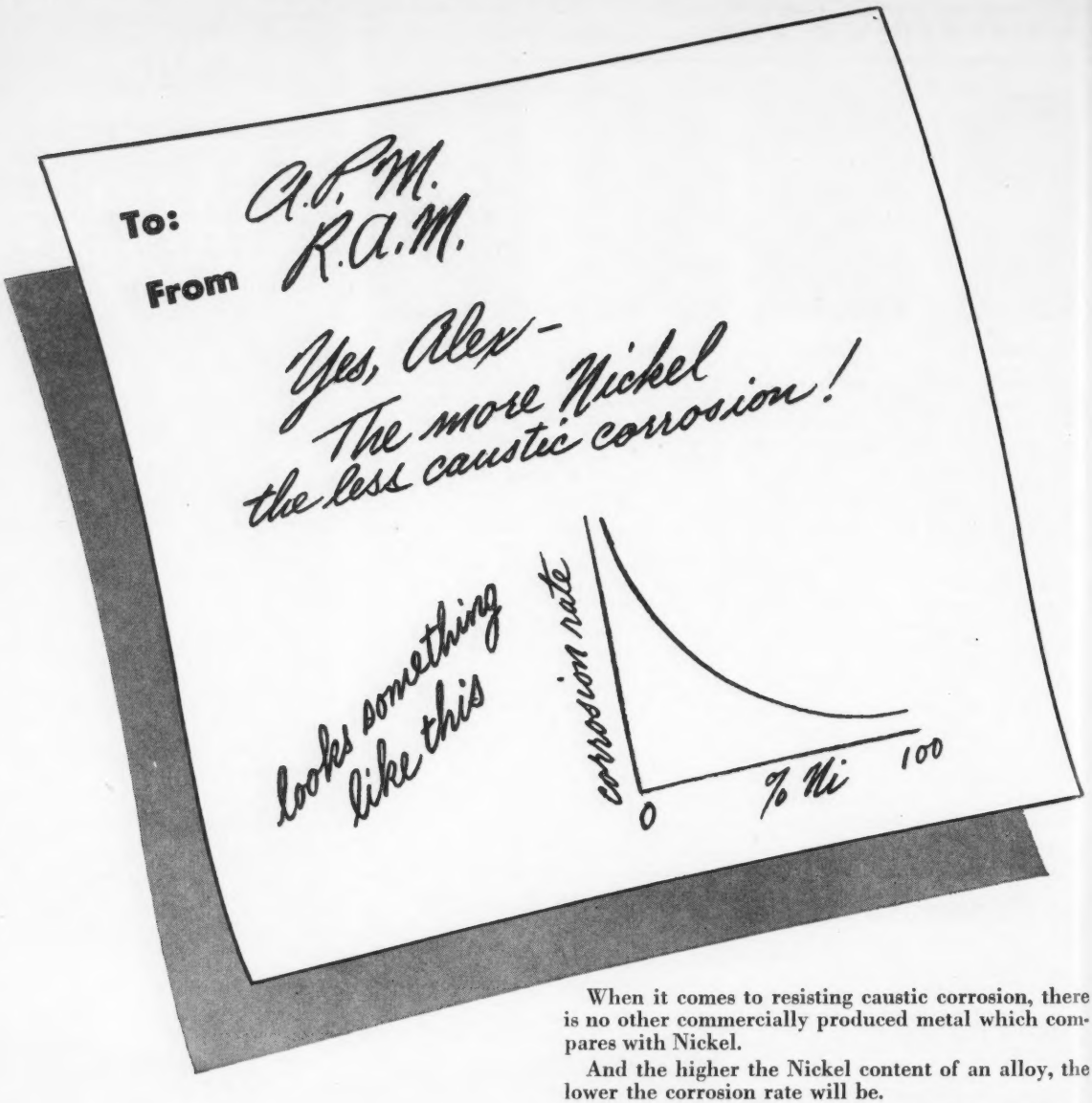


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## Reports on Conference Heard by Directors

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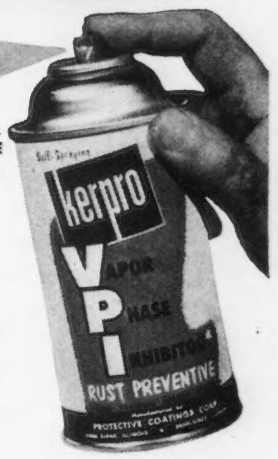


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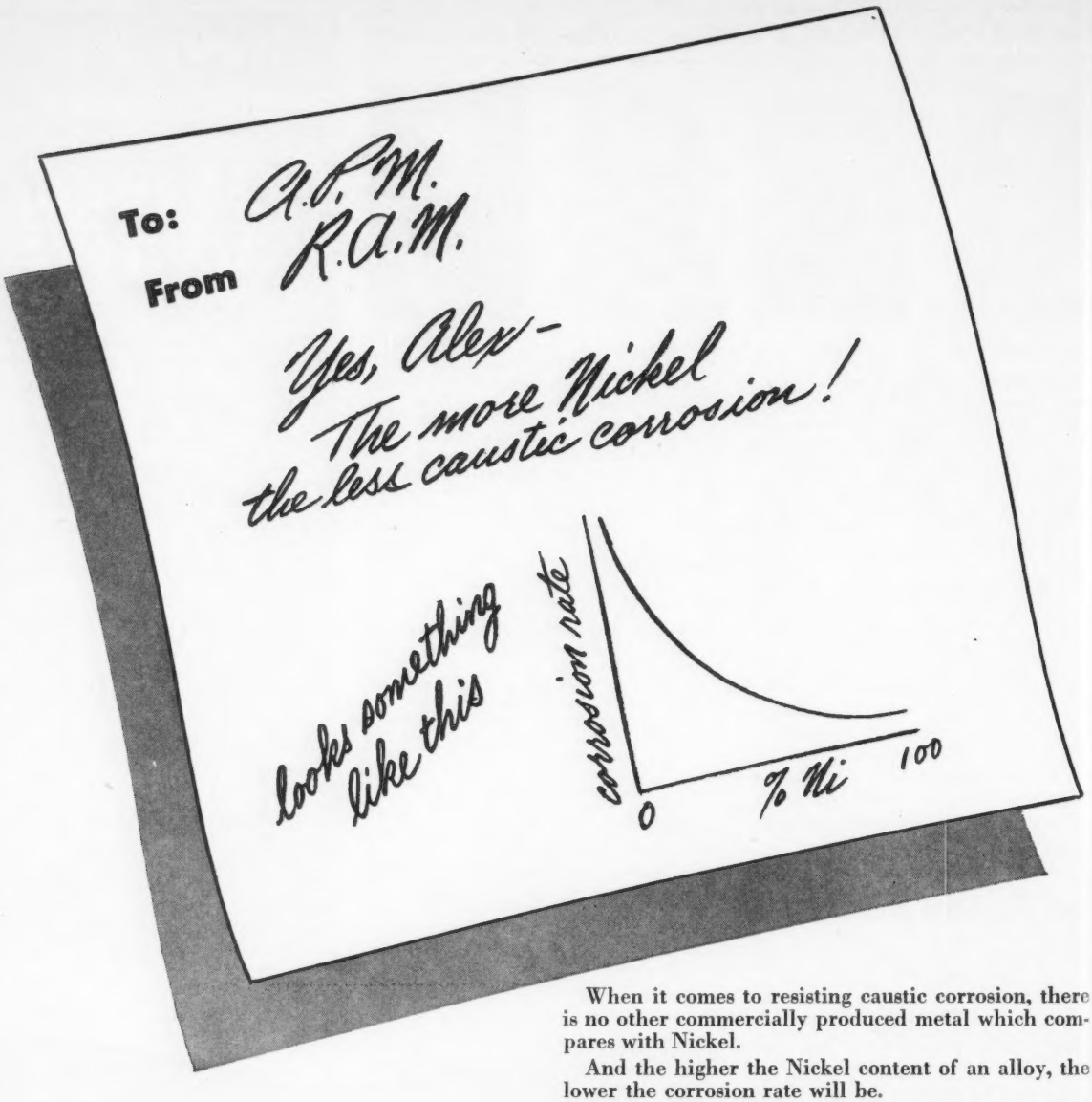


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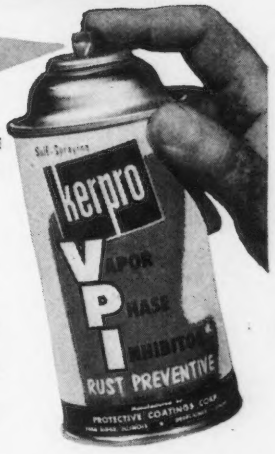


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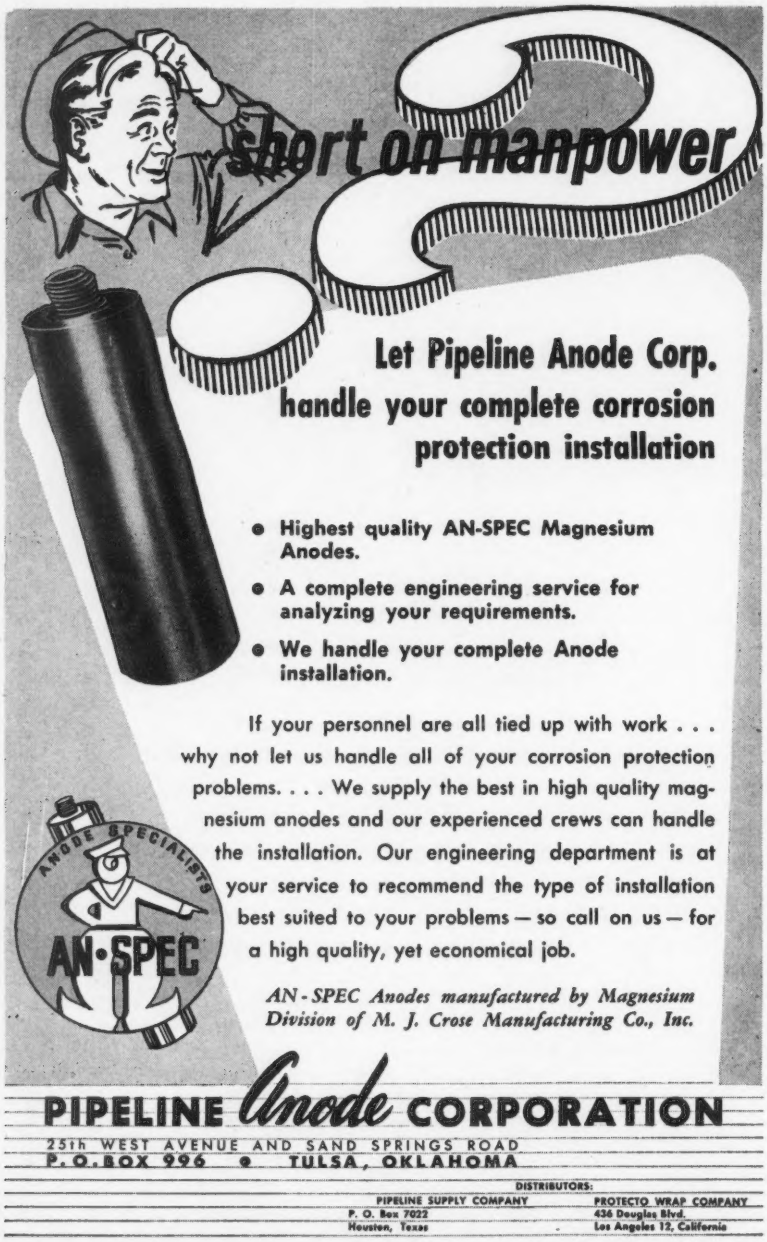
## Board Makes Decisions On NACE Publications

The NACE board of directors at a meeting held at Kansas City, December 4-5 made the following decisions concerning publications of the association:

1. The 1954 Yearbook, to contain a membership and committee directory and other items, will be produced for distribution in June or July, 1954. In years past it has been the custom to publish the membership directory in CORROSION magazine and to issue a separate committee directory.

2. Publication of the 1948-49 Bibliographic Survey of CORROSION is now underway. There is some expectation this volume will be completed in time for the 1954 conference. Work has been started also at Central Office on the 1950-51 Bibliographic Survey with the expectation this volume can be completed by the end of 1954. These two volumes will bring to 5 the number of abstract books prepared by the association. Abstracts covering the years 1945-51 will then have been published.

3. Henceforth orders to NACE for publications whose aggregate value is less than $5 must be accompanied by a remittance. This action was taken in view of the increasing cost of processing and handling orders involving small amounts, the handling costs frequently exceeding several times the value of the publication.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## 1957 Conference to Be Held at St. Louis, Mo.

The 1957 Annual Conference and Exhibition of NACE will be held at Kiel Auditorium, St. Louis and the 1958 conference on the West Coast, at a city to be selected after recommendations are received from a committee of Western Region members.

Conferences now have been arranged as follows:

10th—Kansas City, March 15-19, 1954.
11th—Chicago. Palmer House. 1955.
12th—New York. Statler Hotel. 1956.
13th—St. Louis. Kiel Auditorium. 1957.
14th—West Coast, site to be determined. 1958.

## Pressure Piping Safety Corrosion Advice Asked

A proposal by the chairman of the American Standards Association Sectional Committee on Code for Pressure Piping B31 that NACE furnish technical advice on corrosion needed by his committee has been referred to the chairman of the NACE Technical Practices Committee. The NACE board of directors considered and referred the request at its December 4-5 meeting in Kansas City.

## Houston University Coatings Course Open

Study of protective coatings, including industrial primers, finish coats, emulsion paints, lacquers and vinyls is available to interested persons in a course opening February 1 at the University of Houston. Properties and application methods and the raw materials involved will be covered.

The course, classes for which are held Mondays and Wednesdays from 6:30 to 9:30 pm on the university's main campus, is sponsored by the Educational Committee of the Houston Paint and Varnish Production Club. Lectures are given Mondays and laboratory periods held Wednesdays. Fee for the semester is $50. Those wishing to take the course, available for audit only, may register for Chemistry 450 at the university's registrar's office on January 28 or 29.

## New Iron-Base Alloy Developed at Battelle

A new iron-base alloy, developed as a substitute for stainless steel in the reinforcing braid of Signal Corps lightweight communications cable, should be useful in other applications requiring a material that has moderate corrosion resistance, good workability, and is not easily magnetized, according to Batelle Memorial Institute scientists H. O. McIntire and George Manning. Facts on the new alloy were revealed in a report the two metallurgists made at the annual meeting of the Wire Association held in Chicago last November. Batelle Memorial Institute is in Columbus, Ohio, 505 King Ave.

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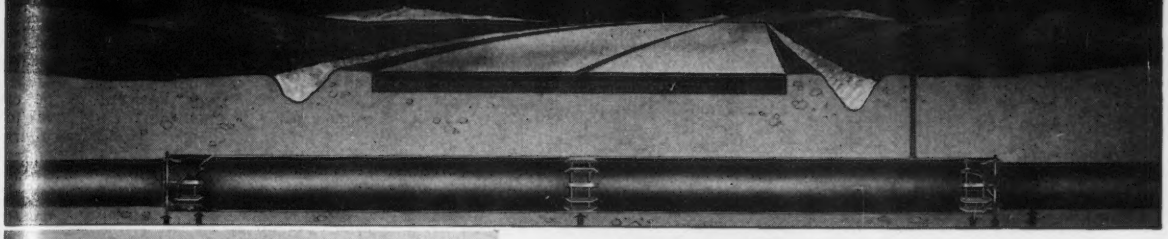

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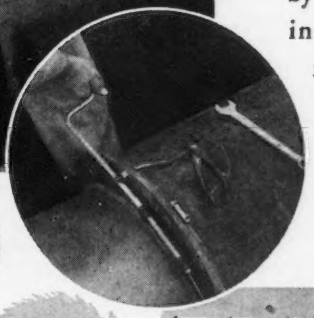

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# Technical Committee Operation Manual Approved

A manual defining the organization and functions of the Technical Practices Committee of the National Association of Corrosion Engineers has been approved by the association's board of directors. Its provisions are scheduled to go into effect immediately.

Principal changes immediately obvious include:

1. New nomenclature for the committee's subdivisions: The Technical Practices Committee, first echelon of the new organization will consist generally of the chairmen of the next lower echelon, to be called

2. Technical Group Committees, which are made up of the chairmen of the last echelon, to be called

3. Technical Unit Committees. There is no limit on the number of unit committees which may be formed, but a procedure is set up whereby formal application through the chairman of the appropriate Group to the Technical Practices Committee itself must be made before a new Unit Committee may be organized.

### All Must Be Members

Another significant change is that henceforth, all members of all echelons of the technical committees must be members of NACE before they can become members. This is a departure from previous practice, which permitted nonmembers to belong to the technical committees.

The regulations also prescribe that there shall be at least one meeting yearly for each Group and Unit committee and that semi-annual progress reports shall be made. Terms of officers also are defined and procedures for election and reelection stipulated. Means for termination of units because of completion of work, inactivity or for other reasons are provided.

Changes of objectives and scope of units must be presented for approval to group chairmen before Unit members vote on the proposed changes. Changes must be approved ultimately by the Technical Practices Committee itself.

### Technical Report Procedure

An outline of procedure for preparation and presentation of technical reports is given which requires approval by Unit members, Group chairman and then the Technical Practices Committee chairman. Procedure for distribution of copies is given.

The complete manual adopted follows:

### Technical Practices Committee Organization and Procedures

#### Objects

The Technical Committees provide a means whereby interested individuals may cooperate in the solution of corrosion problems and in obtaining information leading to prevention of corrosion. The general objectives of the Technical Committees are the same as those of the NACE:

A. To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

B. To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

C. To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

D. To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

E. To promote standardization of terminology, technique, equipment, and design in corrosion control.

F. To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

G. To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

H. To invite a wide diversity of membership, thereby insuring reciprocal benefits between individuals and corporations.

#### Organization and Procedures

The organization shall be as follows:

**Technical Practices Committee**
**to**
**Technical Group Committees**
**to**
**Technical Unit Committees**

The committees conducting technical

(Continued on Page 16)

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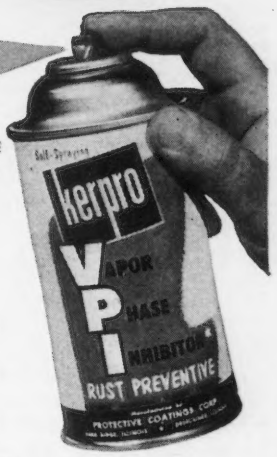


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## Technical Committee—

(Continued from Page 14)

projects shall be known as Technical Unit Committees. According to subject these will be grouped together for coordination and administrative purposes under a number of Technical Group Committees which in turn will be responsible to the Technical Practices Committee.

### Technical Practices Committee

The Technical Practices Committee shall coordinate the functioning of all the technical committees. It shall establish procedures necessary for orderly business conduct of the committees. It shall stimulate committee activity and aid in initiation of new activities. Through its chairman it shall make recommendations to the board of directors for changes or powers to more effectively achieve the aims of the technical committees. In general, it shall advise and act on matters of policy and planning affecting the technical committees.

The Technical Practices Committee shall consist of a chairman, vice-chairman, the vice-president of NACE, and the chairmen of each of the Technical Group Committees. The vice-chairmen of the Group committees shall be alternates for their corresponding chairmen.

The chairman of the Technical Practices Committee shall be appointed by the president of NACE (generally selecting the vice-chairman for the appointment) for a term of two years (counting from last day of the next national conference). The chairman may be reappointed at the expiration of his term, but only for a specified period not exceding two years. Reappointment shall be for special reasons and should be an unusual occurrence. The chairman shall be an exofficio member of the board of directors of NACE.

The vice-chairman of the Technical Practices Committee shall be appointed by the president of NACE when a vacancy arises, preferably selecting a past member of the Technical Practices Committee.

The chairman and vice-chairman of the Technical Practices Committee, together with the vice-president of the NACE, shall constitute the Managing Committee which shall act for the Technical Practices Committee subject to approval of the Technical Practices Committee at a regular meeting of the latter.

**Technical Practices Committee Meetings.** The Technical Practices Committee shall meet at least once each year. One meeting shall be held during the national conference. Notice, including proposed agenda, shall be sent by the chairman to Technical Practices Committee members in advance of each meeting. It shall be the responsibility of the vice-chairman to prepare the minutes of the meetings. Copies of the minutes shall be sent to each member and alternate of the Technical Practices Committee and to the president of NACE.

**Technical Practices Committee Reports.** The chairman of the Technical Practices Committee shall submit a report to the president prior to the executive committee summer meeting (usually in July) summarizing the status of all the technical committees and introducing matters requiring executive committee action or counsel. A report shall also be submitted to the president in February of each year summarizing the progress made during the past year and plans for the future. The latter report would serve as the basis for the report to the members of NACE presented by the chairman at the annual business meeting.

### Technical Group Committees

Each Group committee shall consist of a chairman, vice-chairman and the chairmen of each of the Technical Unit Committees under the jurisdiction of the Group committee. The vice-chairmen of the Unit committees shall be alternates for their corresponding chairmen.

A Group committee may be formed or terminated by the board of directors acting on recommendations from the Technical Practices Committee.

The chairman of each Group committee shall be appointed by the chairman of the Technical Practices Committee, generally selecting the vice-chairman of the Group committee. The chairman of the Group committee shall serve for a term of two years (counting from the last day of the next national conference). The chairman may be reappointed at the expiration of his term but only for special reasons and as an unusual occurrence. In order to avoid replacement of the entire membership of the Technical Practices Committee every two years the terms of the Group chairmen shall start on odd numbered years for the odd numbered Group committees and on even numbered years for the even numbered committees. The vice-chairmen of the Group committees shall be elected when a vacancy arises by letter ballot of the chairmen and vice-chairmen of the Unit committees in the Group. The nominees shall consist of the chairmen of the Unit committees and at least one non-officer member selected by the current chairman and vice-chairman of the Group committee. Each elector shall vote for a first and second choice, the majority of votes cast deciding. Official election results shall be reported by the current chairman of the Group committee to the chairman of the Technical Practices Committee with copies to the chairman of his Unit committees.

**Function.** Each Group committee shall be responsible for establishing such Unit committees as may be required, advising and controlling their procedures. There shall be no fixed limit to the number of Unit committees that may be established under a Group, but Unit committees that are unable satisfactorily to justify their existance shall be terminated.

**Group Committee Meetings.** Each Group committee shall meet at least once each year; one meeting shall be held during the national conference. Notice, including proposed agenda, shall be sent by the chairman to his Group members in advance of each meeting. It shall be the responsibility of the vice-chairmen to prepare minutes of the meetings. Copies of the minutes shall be sent to each member of a Group, to each member of the Technical Practices Committee, and to the president. If a Group does not have the necessary facilities, NACE Central Office shall reproduce and distribute the official minutes.

**Group Reports.** The chairman of each Group committee shall make two status reports each year to the chairman of the Technical Practices Committee, one by June 1, and one by January 1, stating meetings held and attendance, actions taken and summarizing the status of the Units within the Group. Copies shall be sent to each member of the Technical Practices Committee.

### Technical Unit Committees

In general, a Unit committee would be formed when some definite activity is proposed and urged by a group of members interested in the problem or subject matter and when substantial sentiment for the activity exists in industry. The steps to be taken in forming a new Unit committee shall be as follows:

1. A written proposal by or for a group of members shall be submitted to the Group committee chairman with copy to vice-chairman stating the nature of the problem, its importance, range of interest, benefits that could be derived from the activity, specific objectives and possible means of attainment, and list the interested members (a copy of this communication should also go to each of them).

2. The chairman and vice-chairman of the Group committee shall take action, consulting their Unit committee chairmen if desired, and pass the proposal with recommendations for acceptance, modification, or rejection to the chairman of the Technical Practices Committee with copies to members of the Technical Practices Committee.

3. The Technical Practices Committee shall consider the proposal and take action, which may involve modifying recommendations and vote on acceptance of the proposal. Considerations of the Technical Practices Committee should include possible conflicts with existing Units, appropriate Group location of proposed Units and title for the proposed Unit.

4. The chairman of the Technical

(Continued on Page 17)

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## Technical Committee—

(Continued from Page 16)

Practices Committee shall inform the chairman of the Group committee of the Technical Practices Committee's decision and suggest an official title for the Unit Committee.

5. The chairman of the Group committee shall inform each of the proposing members of the Technical Practices Committee's decision, stating reasons if proposal is rejected. If the proposal is accepted, he shall appoint a chairman of the new Unit committee and advise him of further procedures and the responsibilities of his office and of the Unit committee. The chairman and vice-chairman shall be members of NACE.

**Procedure for Initial Organization of a Unit Committee.** The appointed chairman shall call an organization meeting of those who have made the proposal and include others with a strong interest in this activity. (It is suggested that such a meeting be held on the occasion of a regional meeting or national conference.) The chairman may appoint a secretary pro tem to record the minutes of this meeting. This meeting shall attempt to decide on an official statement of specific objectives of the committee and plan means for achieving its aims. If possible, it hall allocate work assignment to individuals or task groups. It shall consider an official title for the committee to be submitted for approval to the chairman of the Group committee. It shall make up an official initial membership list. It should obtain additional names of those who are likely to have a strong interest in the activities of the committee and who should be invited to participate.

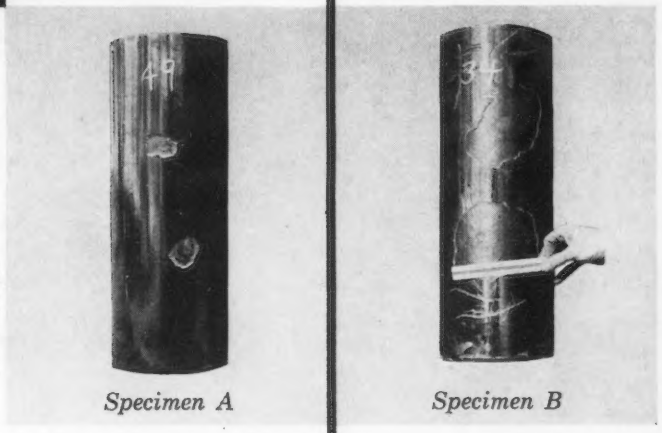
The chairman shall appoint a nominating committee of three members to select at least two, but not more than three, nominees for vice-chairman. This nominating committee should meet and then inform the chairman of its choice immediately following the organization meeting. The chairman shall send a letter ballot to all committee members within four weeks following the organization meeting. The deadline for return of the ballots should be three weeks from the mailing date. A majority of those voting shall elect the vice-chairman.

The chairman of a Unit committee shall serve for two years, counting from the last day of the next national conference, but may be re-elected by majority ballot of votes cast by Unit committee members to continue for additional terms. The ballot, therefore, should list the current chairman and vice-chairman as the only nominees for chairman and should list the current vice-chairman plus one member as nominees for vice-chairman. In the event of resignation of the chairman, the vice-chairman shall assume office of chairman, and an election for a new vice-chairman held within six months. The current chairman shall inform the chairman of the Group committee of results of all elections with a copy to the chairman of the Technical Practices Committee.

**Membership in Unit Committees.** All enrolled committee members shall be members of NACE. Non-members of NACE may attend open meetings as guests. Anyone who desires to become a member of a Unit committee may

(Continued on Page 18)


BETTER BOND ON SPI C/W PIPE WITH STEEL-GRIT CLEANING



*Specimen A* *Specimen B*

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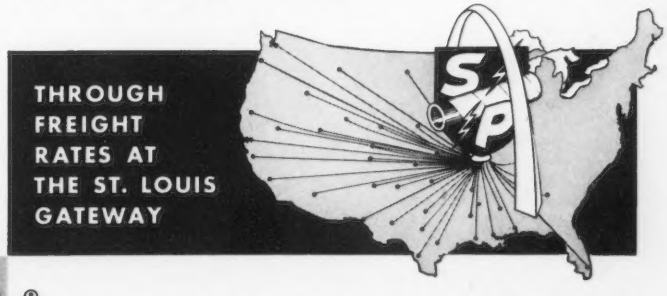


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## Technical Committee—

(Continued from Page 17)

apply in writing to the chairman of the Unit stating his interest and willingness to participate in the activities of the Unit and giving his experience in the subject. If the chairman approves, he shall appoint the applicant a member, with copy to the chairman of his Group. If the chairman does not approve or has serious doubts, he shall call for a letter ballot vote of the Unit members, a majority vote deciding. The chairman should urge those whose participation is desired, to apply for membership. Membership by appointment without written application may be allowed in special cases provided concurrence of the Group chairman is obtained.

A member may be removed from the Unit committee roster by the Unit chairman for lack of participation or unwillingness to cooperate in the work of the committee. This shall be explained to the member in writing by the chairman (copy to Group chairman) stating reasons and indicating that member would be dropped at a given date unless member desires to remain and can offer evidence of activity. A member who foresees a protracted period of inactivity and desires to remain on the roster should notify his chairman, stating the reasons and that he will resume active participation at the end of this period.

**Termination of Unit Committees.** A Unit committee may be terminated by majority vote of the Technical Practices Committee acting on the recommendation of the Group committee chairman. Termination is in order if the Unit has been inactive for more than one year or if at least ⅔ of the members vote in favor of termination (e.g., for reasons of project completion, inactivity, or disappearance of interest). The Group committee may, at its discretion, call for a ballot vote of Unit members on the question of termination.

The Technical Practices Committee may, at its discretion, question justification for continued existence of a Unit committee, directing such question to the chairman of the appropriate Group committee who then shall investigate and summarize the facts and recommendations to the chairman of the Technical Practices Committee. Actions of a Unit that are unethical and inimical to the aims of NACE shall constitute justification for termination.

**Change of Unit Committee Objectives and Scope.** A Unit committee may change its objectives by a 2/3 vote of letter ballots cast. This may occur when the Unit's project has been completed or when attainment of initial objectives appears impractical. The letter ballot on this question shall also request each member to indicate if he desires to participate in the work of the Unit with the new objectives if adopted. The title of the Unit and the appropriateness of the Unit remaining within the same Group shall not change. Approval of the chairman of the Group shall be obtained prior to the vote, informing him of the change in objectives, the reasons, and projected means of attainment. The chairman of the Technical Practices Committee shall be informed of changes in objectives that are adopted.

Change in scope and title of a Unit committee shall require approval of the Technical Practices Committee as in initiation of a new Unit committee. If the change is approved and adopted, the initial membership list shall include those existing members who have affirmed their desire to participate in the work of the revised committee.

**Duplication of Unit Committee Activities.** Duplication or substantial overlap of activities of different Unit committees shall be avoided insofar as possible. If a problem of duplication arises, it shall be resolved by the chairman of the Technical Practices Committee.

**Task Groups of Unit Committees.** It is often expeditious for a Unit committee to accomplish its work through appointed task groups consisting of one or more members. Action along such lines is solely within the discretion of the Unit committee. It is generally most advantageous if the work assignment of a task group is very specific and if the assignment can be scheduled for completion by a set date. A task group is usually dissolved after it completes its assignment.

**Reports of Unit Committees.** Status reports shall be made twice each year to the chairman of the Group committee, one in May and one in December. These reports shall summarize briefly the status of the Unit's current activities, including statement of the meetings held and attendance, membership changes, reports issued, business transacted, task assignments, progress status of its various activities, plans and action taken on further work, and other appropriate matters. Copies shall be sent to all members of the Unit, to the Group committee and to all members of the other Units in the Group. NACE Central Office shall reproduce and distribute copies of status reports.

**Technical reports** in general would consist of 1) compilations of technical information and opinions without official conclusions or recommendations (although proposals may be made for the latter), or 2) organized and digested technical information with official conclusions and recommendations, if possible, or 3) final complete report on a specific activity. In some instances it would be desirable prior to official issuance for a report to be circulated to all members of the Unit for corrections, additions and comment. Every Technical Report intended for general release as an NACE Report, shall be submitted to each member of the Unit who shall vote as "approving," "disapproving" or "not voting." The report shall not be released if 25 percent or more of members voting disapprove. To be valid, a vote of disapproval must be accompanied by reasons. Attempt shall be made by the authors of the report to eliminate objections. Unreconciled objections shall be transmitted with the report to the Group chairman who shall transmit them to Technical Practices Committee chairman or return the report to the Unit for further work. Approval of the Group chairman and Technical Practices Committee chairman shall be required to establish it as an official NACE Technical Committee Report. Suggestions for special distribution, if any, should be made by the Unit chairman when the copies are submitted for approval. The chairman of the Technical Practices Committee shall notify the Central Office and chairman of the Publication Committee of approval and recommendations for publication and distribution. The NACE Central Office shall reproduce and distribute the official copies. Each member of the Unit shall receive a copy of the issued report, as well as the members of the Group Committee and each member of the Technical Practices Committee. NACE shall have prior rights to publication of a committee technical report; exceptions shall require approval of the chairman of the Technical Practices Committee. A copy of each technical report shall be made available gratis to all corporate members of NACE. Technical reports shall be made available to Active and Junior members of NACE at a lower price than to non-members.

**Meetings of Unit Committees.** Unit Committees shall meet at least once each year (once during the annual conference). Notice including proposed agenda shall be sent by the Unit chairman to his members in advance of each meeting (copy to Group chairman). It shall be the responsibility of the Unit vice-chairman to prepare the minutes of the meetings. Minutes shall be distributed to members of the Unit and Group committees within six weeks following the meeting. At the discretion of the Unit chairman minutes may be sent to guests attending the meeting. If the Unit does not have the necessary facilities, NACE Central Office shall reproduce and distribute the official minutes.

### Correspondence

The normal flow of correspondence on the business of the Technical Committees shall be as follows: member←→chairman of Unit←→chairman of Group←→chairman of Technical Practices Committee, except as may be indicated elsewhere in the procedure guide. **Copies of all correspondence, minutes, and reports shall be sent to Central Office.**

### Records

The chairman of each Unit committee, Group committee, and the Technical Practices Committee shall keep an official file for his committee which shall include minutes of all meetings, a copy of all official technical reports and of all status reports. This file shall be passed to a succeeding chairman together with a file of letters relating to current business and incomplete material for technical reports.

### Relations With Other Organizations

Agreements with groups or organizations outside the NACE shall be subject to approval by the Executive Committee of NACE. Appointment of a member as official NACE representative to an outside group or organization shall be made by the President advised by the Technical Practices Committee chairman. The powers of such an appointee shall be defined by the Executive Committee.

### Expenditures

The technical committees (Units, Groups and Technical Practices Committee shall not incur expenditures of association funds without prior approval of the Executive Committee of NACE. NACE funds generally are not available for these activities.

(Continued on Page 20)

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## Numerous Papers Given At Thermodynamics Meeting at Stockholm

Numerous papers under four headings were presented at the Fifth Annual Meeting of the International Committee of Electrochemical Thermodynamics and Kinetics at Stockholm, Sweden, July 25-26, 1953. Attendance was about 100 including representatives from about 10 of the 18 countries represented in the organization. Pierre Van Rysselberghe, University of Oregon, Eugene, who attended the meeting, reported the opening session covered a review of the committee during the year. A list of 19 national secretaries for the committee was established.

Plans were announced for early publication of the proceedings of the first, fourth and fifth meetings of the committee. Proceedings of the second and third meetings have been published and are available from Secretary-General Marcel Pourbaix, University of Brussels, Belgium. Information about the meeting can be obtained from Prof. Van Rysselberghe and from H. H. Uhlig, Massachusetts Institute of Technology, Cambridge.

The technical program consisted of: Electrochemical Fundamentals, Nomenclature and Definitions, with a report on the commission of Nomenclature and Definitions by Prof. Van Rysselberghe. There were eight papers under this heading.

Experimental Methods in Electrochemistry, with a report by R. Piontelli, Institute of Technology, Milan and six papers.

Electrochemical Behavior of Metals and Non-Metals, including presentation of the potential-pH diagram of zirconium by Prof. Van Rysselberghe and M. Maraghini, University of Rome and a series of nine papers on applications of potential-pH diagrams and on polarization curves.

Applications to Corrosion, covering the following titles: Polarization Resistance and Corrosion of Iron, K. F. Bonhoeffer and collaborators, University of Gottingen, Germany. Dissolution of Iron and Steel in Acids, T. P. Hoar, University of Cambridge, England. Hydrogen Embrittlement of Carbon Steels by Pickling and Electrodeposition, U. Tragardh, Institute of Technology, Stockholm. Protection and Corrosion of Iron Cathodes and the Oxidizing Phosphatization of Ordinary Steels, M. Pourbaix and collaborators. Electromicroscopic and Electron Diffraction Investigations on Various Prepared Zinc Surfaces, K. Huber and D. Laske, University of Berne, Switzerland. Model Studies on the Electrochemical Behavior of Two-Phase Electrodes, G. Bianchi, Institute of Technology, Milan.

A section devoted to various applications, including several papers on polarography was presented also.

## Holbrook Is Honored

George E. Holbrook, assistant director of the development department of E. I. du Pont de Nemours and Co., Wilmington, Del. has been awarded the 1953 Professional Progress Award of the American Institute of Chemical Engineers.

## Translation Service Is Available Now From Libraries' Association

Photoprint or microfilm copies of translations may be obtained from the Special Libraries Association, Chicago, Ill., under a new service provided by the association in cooperation with the John Crerar Library. Currently, the rates are $1.40 for ten pages, or fraction thereof of photoprint; or fifty pages, or fraction thereof of microfilm, plus a service charge of $1.00 for each translation, payable in advance.

The association has deposited 1300 translations in the Crerar Library to form the nucleus of the pool. In the near future, a list of these translations will be available for distribution and arrangements are under way for the listing of future contributions in technological journals in the fields covered by the translations. The association is soliciting contributions of translations from government agencies, technical societies, universities, industries and individuals. Contributions may be made by the deposit of good copies of complete translations. Address of the association is: S. L. A. Translations Pool, John Crerar Library, 86 East Randolph St., Chicago 1, Ill.

## Agreement Negotiated On Getting Test Coupons

An agreement whereby test coupons for in line tests may be secured by members of Technical Practices Subcommittee 18-B on Internal Corrosion of Products Pipe Lines is now being negotiated. This information was given in minutes of a meeting of the sub-committee held April 19, 1953 at Kansas City, distributed by Ivy M. Parker, committee chairman.

Specifications for the coupons were discussed, including surface preparation, type and condition of metal, packaging, data recording and other details.

## Technical Committee—

(Continued from Page 18)

**Solicitation of Funds.** In general, it is expected that the work of a Technical Committee can be accomplished through voluntary contribution of time and materials by participating members and the organizations whose interests they represent. This may include, for example, clerical work, or labor and materials for field tests. Occasionally, the foregoing is impractical or insufficient and it may become necessary to obtain money from outside sources for costs in achieving certain objectives of the committee. Such an occasion may arise if sponsorship of research at a university or institute is required. In that event, the following procedure shall be followed: The chairman of the Unit committee shall submit a plan to the chairman of the Technical Practices Committee (copy to Group chairman) stating the amount to be raised, the purpose, the time period that the project will cover, contract arrangements required, how the money is to be expended and in general who is to be solicited. The chairman of the Technical Practices Committee shall submit the plan with recommendations to the Executive Committee. If the plan is approved by the Executive Committee, the Unit committee shall prepare a letter of solicitation and a list of names and addresses to whom it should be sent, for review by the chairman of the Technical Practices Committee (copy to Group chairman) who shall then forward it to the president. The official letters of solicitation shall be signed and sent out by the president. Questions from addressees shall be handled by the president or referred by him to the Unit chairman. Follow-up letters to those that do not respond shall be prepared by Unit chairman for sending by the president. The chairman of the Unit shall direct disbursal of funds by Central Office (copies to president, Technical Practices Committee chairman, and Group chairman).

When the time period stipulated has expired or the project has terminated, the chairman of the Unit committee shall prepare an approximate accounting of sums disbursed and of accomplishments for distribution to contributors by the president after approval by the Executive Secretary and the chairman of the Technical Practices Committee. If surplus funds remain at that time, the accounting letter shall also contain proposals for its handling. Surplus could be expended in further research on the project, or the choice offered each contributor to receive a proportionate refund on his contribution or to contribute this sum to a general research account of the NACE.

### Questionnaires

Questionnaires for circulation to members outside a single Technical Committee Unit or to non-members of NACE shall require approval of the Technical Practices Committee chairman prior to distribution. Assistance of Central Office may be sought in reproducing and distributing approved questionnaires.

### Reorganization Plan

This plan follows the procedure outlined in the procedure manual dated September 2, 1953.

Under this plan TP-1 will remain intact except that the work of the Pacific Coast group will be identified under the respective unit committees as the "West Coast Region Committee." That work which the Pacific Coast is now doing but which is not represented by a unit committee will be given to a newly formed unit committee.

All purely local technical activity will be handled in this manner in the future, i.e., through the formation of a regional committee under the appropriate unit committee.

A new group committee, TP-2, Oil and Gas Pipe Lines, will be formed. To this committee will be allocated the present TP committees 2, 3, 4, 17, 18-A and 18-B.

The new TP-3 will be known as "General" under which will be placed TP committees 9, 11, 13, 14, and 15.

TP-4 will be known as "Utilities," and will consist of TP-8, 12, 16, and 19.

TP-5 will be "Corrosion Problems in the Process Industries" and will consist of TP-5, 7, and portions of TP-8.

TP-6 will be "Protective Coatings" and will consist of the present TP-6.

## Some Gains Are Made by Corrosion During 1953

Some statistical gains were made by CORROSION during 1953 in comparison with similar achievements in 1952. Principal gains were 28 pages in the technical section and 6 titles in the index.

A comparison of the two years is given below:

| | 1952 | 1953 |
|---|---|---|
| Titles in index | 70 | 76* |
| Reprinted articles | 8 | 7 |
| Technical Section pages | 439 | 467 |
| Authors | 162 | 128 |
| Discussions | 111 | 86 |
| Pages in Abstract Section | 190 | 141 |
| Total pages | 1394 | 1404 |

* Titles of 11 Topic of Month articles deducted.

## BOOK REVIEWS

**Modern Electroplating.** 563 pages plus XII, 5¾ x 9 inches, cloth. 1953. Allen G. Gray, Editor. Sponsored by The Electrochemical Society, Inc. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. Price not indicated.

An exposition of modern electroplating theory and practice by 39 authorities. Contents range from general principles through methods of control and include separate sections on each of the commonly electroplated metals. An appendix of 15 pages gives tables of useful data for electroplaters.

The sole indexed item on corrosion covers a corrosion test for gold.

Each section includes numerous references to related technical material.

**Portfolio of Materials File Facts for Engineers, Designers, Metallurgists and Production Men.** New Revised Fourth Edition, 112 pages, 8½ x 11, paper cover. Reinhold Publishing Corp., 330 W. 42nd St., New York 36, N. Y. Availability not indicated.

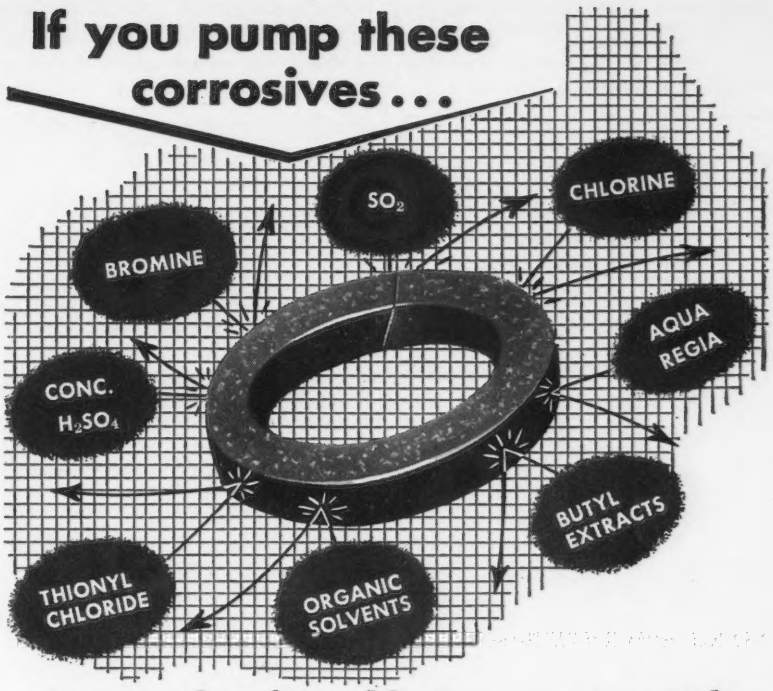
Useful facts about irons and steels, a special section on stainless steels, and other sections on nonferrous metals, nonmetallic materials, plastics, a section on heating and heat treating methods, and one on miscellaneous materials and engineering data are given.

Among the many tables listing properties, uses, specifications, and classifications of materials are separate pages devoted to: Resistance of Several Stainless Steels to Various Corrosive Media; Corrosion Resistance of Titanium Metal in a Number of Chemical Reagents; Comparison of Corrosion Properties of Zirconium, Titanium, Tantalum, Stellite No. 6 and Type 316 Stainless Steel; Relative Corrodibility of Metals and Alloys (excepting stress corrosion); and Metals for Use with Highly Corrosive Media.

**Symposium on Diesel Locomotive Engine Maintenance.** 146 pages, 6 x 9 inches, paper cover. American Locomotive Company, Public Relations Department, Schenectady 5, N. Y. Free.

Contains the following papers presented at a meeting at Schenectady May 11-12, 1953: Progress Report on Spectroscopy,

(Continued on Page 23)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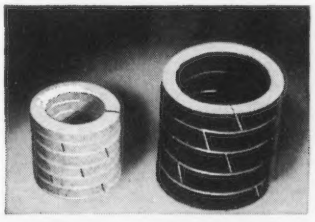

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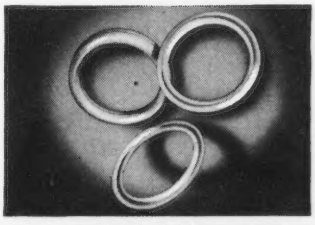

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**Write for Rates**

**Advertising in this Directory costs about $1.25 a thousand circulation in 46 states and 40 foreign countries**

## BOOK REVIEWS

(Continued from Page 21)

which consisted of reports on the experience of nine railroads reported by their representatives. Consensus is that spectroscopic analysis of lubricating oil permits operators to be warned in advance of coming mechanical trouble. Some unexplained erratic reports are cited. Other papers are Comparative Laboratory Results, A Report on Comparative Spectrographic Laboratory, The Control of Railroad Lubricating Oils, Mixing of Lubricating Oils, Reclaiming Used Diesel Engine Crankcase Oils, Lubricating Oil Control Testing Methods (Six Parts), Lubricating Oil Filtering and Filtering Media, The Electron Microscope, Air Filtration, Maintenance of Air Filters (Four Parts), Ail Filter Coating Oils, Birmingham Southern Experiences With Filters and Oils, Diesel Engine Cooling Water Treatment With Nonchromate Compounds and Diesel System Cooling Treatment.

The last two papers deal with the history of cavitation erosion and with the use of chromates. Tests are reported underway using borates, nitrates, silicates, soaps, mercapto-thiozoles, sodium carbonate, sodium phosphate and others.

(Continued on Page 24)

## POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Firms seeking employees, regardless of NACE membership, may run an advertisement of the same specifications indefinitely.
- Advertisements to other specifications will be charged for at standard rates.

### Positions Available

**Corrosion Engineers.** Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

**Sales Representatives** for DEL Protective Coatings. Protected territories available to qualified individuals or companies. No objection to carrying noncompetitive lines. Write David E. Long Corp., 220 East 42nd St., New York 17, N. Y.

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**Salesmen**—Would you like to add a protective coating to your line? If so advise territory covered and items now handled. 40% commission. Corrosion, Box 53-19.

**Industrial Sales Engineer**—Progressive organization established in corrosion control field has Midwest opening for salesman with practical engineering knowledge, capable of interpreting power and processing plant maintenance needs in terms of equipment-engineered protective coatings. Salary, expenses and incentives. Corrosion, Box 53-20.

•

Articles on meetings pertaining to corrosion control held anywhere in the world are welcomed for publication in CORROSION, NACE official monthly magazine.

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**REQUIREMENTS** — Metallurgy or Physical Chemistry or Chemical Engineering at doctorate level with experience preferred.

Management positions in leading ferrous industry. Duties entail planning, coordinating, and developing profitable research programs in:

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Water treatment for corrosion control in buildings, boilers and air conditioning systems.

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# NBS Tests Provide Data on Fatigue Properties of Helical Music Wire Springs

AN INVESTIGATION of the fatigue properties of music wire and springs, which is now under way at the National Bureau of Standards, has resulted in the development of a reversed bending analysis method for predicting the approximate fatigue strength of helical springs wound from music wire. The study, which is being conducted by J. A. Bennett, H. C. Burnett and C. L. Stangaitis of the NBS mechanical metallurgy laboratory, has also yielded information about the mechanism of failure of wire springs.[1]

Many ordnance devices such as machine guns and small arms are dependent on helical springs for their operation. These springs operate over a very large stress range and must maintain their original strength through thousands of cycles. Music wire is most frequently used for springs in ordnance devices because it is the strongest engineering material available. Small-diameter wire of this type is produced commercially with a tensile strength as high as 450,000 pounds per square inch. The reversed-bending study, made on four types of wire, is the first phase of the bureau's investigation of helical springs. The work is sponsored by the Army Ordnance Corps.

In the NBS investigation reversed bending fatigue studies were made using two types of testing machines. One of these was designed and constructed at the bureau; the other was the Hunter wire fatigue tester. The NBS machine utilizes a rotating strut but differs somewhat from other machines of this type. Both machines operate on the principle that a rotating curved wire must reverse its points of maximum compression and tension once each revolution. Approximately 50 specimens of four types of wire were studied under reversed bending in the Hunter machine, and 100 specimens of each type in the NBS machine. When results from the two machines were correlated, no consistent difference in data was found.

### Fatigue Studies Made

Fatigue studies of short compression springs were made in another type of machine designed at the bureau. In this device an electric motor and adjustable eccentric are attached to one end of a steel plate which is pivoted at its midpoint. Eight springs, four at each end, are mounted between the pivoted plate and a second fixed plate approximately two inches below. The four springs at each end are positioned at the corners of a theoretical square. This permits the eight springs to be stressed simultaneously at two levels. Stress levels are computed by measuring the change in pitch of each spring when in the no-load minimum-, and maximum-load positions.

In order to provide a comparison between the results of the reversed bending studies and the compression tests, the data obtained were used to prepare tables that give, for various life times, the ratio between the stress range in the springs and the stress amplitude in the wire. These turned out to be similar for all of the four types of wire tested. The NBS data indicate that reversed bending fatigue analysis of music wire will give the approximate fatigue strength at high stress levels of helical springs wound from that wire. However, the correlation was not sufficiently good to differentiate between samples of similar wire.

In the course of the investigation a study was made of the mode of fracture of the springs. In a helical spring loaded in tension or compression the wire is actually twisted. Consequently, there are shear stresses in the wire which are parallel and perpendicular to its length and the tensile stress is at an angle of 45 degrees to these. Observation of the fractures showed that in almost all cases a fatigue crack had started on a longitudinal shear plane and progressed for some distance along the wire before a crack normal to the tensile stress started. Fracture of the wire occurred when the tensile crack had progressed only a short distance. These observations were verified by microscopic examination of a cross section of the wire taken from a fracture. The discovery that fatigue cracks start on a longitudinal shear plane explains one type of failure experienced in machine gun springs, where the strength of the springs decreases greatly without actual failure.

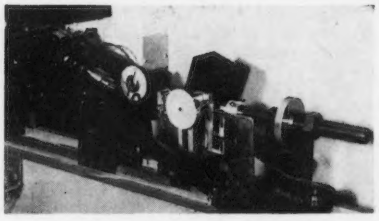

**Figure 1—Fatigue testing machine developed by NBS for use in reversed-bending studies of music wire. The Bureau employs reversed bending analysis of helical springs wound from the same type of wire. The specimen is mounted in the motor chuck and a pivoted tailstock bearing.**

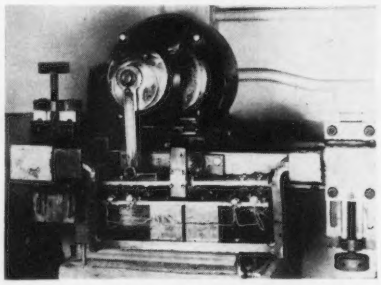

**Figure 2—Fatigue studies of short compression springs were made on a machine also developed at NBS. In this device the motor and adjustable eccentric from a Krouse plate bending machine were utilized, allowing eight springs to be stressed simultaneously at two levels. Stress levels are computed by measuring the change in pitch of the spring when in the no-load, minimum-load, and maximum-load positions. Electrical contacts stop the motor if any specimen fractures.**

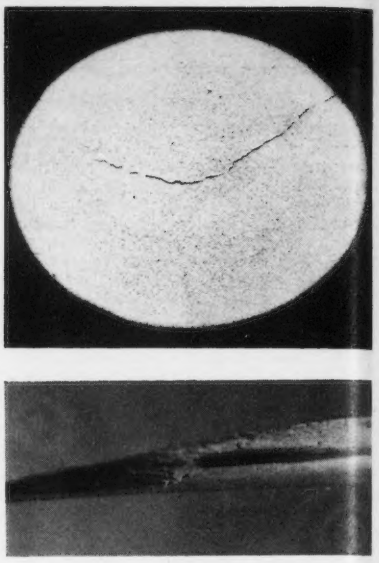

**Figure 3—A cross section of a spring that failed in the NBS study shows a fatigue crack which developed along longitudinal planes in the wire. The section is some distance from the fracture. The study showed that initial fatigue failure of the compression springs occurs on longitudinal planes of maximum shear stress in the wire. (1) The crack progresses for some distance along the wire before a crack normal to the tensile stress is started. (x 50.) (2) Typical fracture of helical compression spring wound from music spring wire.**

1. Endurance of Helical Springs Related to Properties of the Wire. H. C. Burnett, C. L. Staugaitis. *Metal Progress*, 64 (1953) Sept.

## BOOK REVIEWS

(Continued from Page 23)

The last paper mentions satisfactory experience with chromate inhibitors to prevent erosion and corrosion of liners. Tests on one nonchromate inhibitor showed it effective on limiting corrosion on one type of engine but not on another. An improved nonchromate is being tested now. Nonchromates are not recommended to stop corrosion. Principal objection to chromate treatment is in the dermatitis it causes.

**Procedures in Experimental Metallurgy.** 5¾ x 9 inches, Cloth. 1953. By A. U. Seyboldt and J. E. Burke. John Wiley & Sons, Inc., New York; Chapman & Hall, Ltd., London. Per Copy.....$7

Interest on the part of physicists and physical chemists in doing experimental work revealing fundamental information about metals creates the need for expanding the available information on reliable procedures. The authors present details of technique, equipment, control and lists of materials for various kinds of tests on metals.

Chapters include: Methods of Obtaining High Temperatures, Measurement of High Temperatures, Control of Temperature, Refractories, Controlled Atmospheres, Vacuum Systems, Melting and Casting, Heat-Treating Techniques, Fabrication of Metals, Powder Metallurgy, Preparation of Pure Metals and Preparation of Metal Single Crystals.

The book is illustrated and indexed.

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# Johns-Manville TRANTEX *polyvinyl* TAPE

## gives lasting protection against pipeline corrosion!

ON JOB AFTER JOB, Johns-Manville Trantex Tape is controlling corrosion and extending the service life of underground gas and oil pipelines.

Trantex is a durable plastic tape that sticks on contact—bonds tightly to the pipeline. No heat or heavy duty equipment is needed in its application. It is easily applied by hand or by specially developed hand-operated machines. Many users have found that field-applied Trantex Tape speeds coating applications . . . lowers construction costs on both large diameter transmission lines and gas distribution systems.

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| | *V-10 | **V-20 |
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| Dielectric Strength per mil thickness, Approx. | 1,000 V | 1,000 V |
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| Temperature Limit | 200 F | 200 F |
| Adhesion oz. per inch width | 30 | 20 |
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"Trantex" is a black polyvinyl tape. It is available in two thicknesses—

*V-10 is a 10 mil tape for average conditions, and

**V-20 is a 20 mil thickness for use where a more rugged coating is specified, such as to repair enamel coatings.

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**Johns-Manville TRANTEX *polyvinyl* TAPE**

**PROTECTS PIPELINES AGAINST CORROSION**

## ASTM Publications Are Ready for Issue

The American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., has distributed special members' order blanks for ordering Fall ASTM publications. Publications are classified under four headings: Compilations of Standards, Special Publications, Symposiums and Four Books Published in June, 1953.

Among the many reports listed are a Symposium on Fretting Corrosion, and one on Porcelain Enamels and Ceramic Coatings as Engineering Materials. The symposium on fretting corrosion includes papers titled: Influence of Fretting Corrosion on the Fatigue Strength of Fitted Members, Effect of Lubricants in Minimizing Fretting Corrosion, and Test Equipment for Evaluating Fretting Corrosion. The symposium on porcelain enamels includes papers on Resistance of Porcelain Enamels to Weathering, The Chemical Resistance of Glass Fused to Steel, and Acid Resisting Properties of Porcelain Enamels.

## Holt Is Honored

Dr. Marshall Holt, Assistant Chief of the Engineering Design Division, Aluminum Research Laboratories, New Kensington, Pa. has been elected president of the Society for Experimental Stress Analysis. He has made contributions to the technology on pressure vessel design and metal fatigue, among others.

## Alcoa Welding Film Available for Loan

"Welding Advances With Aluminum," a demonstration film has been produced by the Aluminum Company of America. The color film shows the latest techniques in the welding of aluminum pressure vessels, offering a comprehensive description of welding aluminum using both the tungsten arc and consumable electrode methods. The motion pictures demonstrate how inert gas methods have simplified manual, automatic and semi-automatic welding of aluminum, including welding of pressure vessels, weld repair of castings, and production of weldments. The basic concepts of both tungsten arc and consumable electrode welding are explained in an animated sequence. The 16 mm film lasts for 28 minutes. It can be borrowed for group showing by writing on company letterhead to Motion Picture Section, 818 Alcoa Bldg., Pittsburgh 19, Pa.

## NACE Cooperates in Seven 1953 Short Courses

Seven short courses were held during 1953 with cooperation by NACE the association's education committee reported to the board of directors at its meeting in Kansas City, December 4-5.

The board also considered a suggestion concerning presentation of one-hour lectures on corrosion topics of field and plant interest at one or more of the regional meetings in 1954.

## Tin Corrosion Studies In England Reported

An article on the testing program underway by the Tin Research Institute, Fraser Road, Greenford, Middlesex, England titled "Corrosion Studies at the Institute," is published in the September, 1953 issue of Tin and Its Uses, a periodical of the institute. The article relates in general terms the manner in which the corrosion resistant properties of tin are determined by exposure to the atmosphere, in kitchens and lavoratories, in sea water and under attack by foods and other agents.

## Exchange of Technical Publications Suggested

The Centro de Documentacion Cientifica Y Technica, Plaza de la Ciudadela 6, Mexico, D. F. a function of the United Nations Educational, Scientific and Cultural Organization, has invited publishers of periodicals in Latin America, and elsewhere in the world who wish to exchange their publications with others to write to the center. Samples of the publication to be exchanged should be sent with the request.

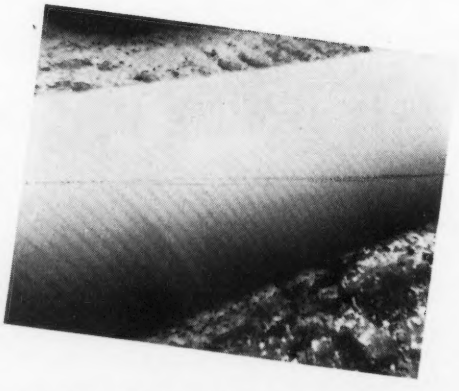
The center will forward the request, together with the samples to journals in which the petitioner is interested.

This information was included in the monthly Bulletin of the center, Vol. 2, No. 11, November, 1953.


# AND NOW — TUFBESTOS!

**manufactured by Nicolet Industries, Inc.**

A new product developed from our revolutionary VITRABESTOS. Production costs of this light weight asbestos product permit a lower price to you. TUFBESTOS is an engineered asbestos felt, reinforced with parallel glass yarn on ¼" centers longitudinally. Does not break in application and assures reinforcing in the outer skin of the enamel as well as acting as a shield. Width 2" to 36". 800' rolls standard length. Special lengths available on request.



**TUFBESTOS joins the family of custom-made Nicolet Felts—15# regular; 15# perforated; 8# and VITRABESTOS.**

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**EASTERN DISTRIBUTOR:**
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**2 Mark Road, Kenilworth, N. J.**

**SOUTHEASTERN DISTRIBUTOR:**
**Anti-Corrosion Mfg. Co.,**
**2464 Memorial Drive, S.E., Atlanta, Ga.**

# NEW PRODUCTS —Materials—Service—Literature

**The Ni-Vee Bronzes,** Bulletin A 107-8, two parts. Part 1 reprinted from magazine *Foundry,* Feb. 1951. Part 2 reprinted from *Foundry,* April 1951. Bulletin, originated with The International Nickel Company, Inc., presents a family of low shrinkage, heat treatable bronzes for machine component pressure and bearing castings, that develop excellent mechanical properties in the "as cast" condition.

•

**An Improved Flanged Joint** for Rubber Lined Piping, an article by G. W. Hauck, Manager of Engineering Sales, The Crane Company appears in the *Crane Valve World,* No. 3, 1953. The article describes the evolution of flanged joints and describes the improved Crane welded joint which is designed to give better continuity to pipe lining.

•

**Corrosion Resisting Properties** of the Austenitic Chromium-Nickel Stainless Steels. Bulletin A-49, with 32 pages and 18 tables, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y. Booklet is a general publication that covers the mechanism of corrosion resistance in stainless steels; factors affecting their corrosion; their behavior in various corrosive environments, marine and industrial atmosphere, in organic and inorganic acid salt solutions and in halogen salts and weak and strong bases; and the preferred practice in construction and use of stainless steels. Shows that nickel in combination with chromium increases the corrosion resistance in both oxidizing and reducing solutions. In addition it has desirable effects in promoting austenitic structure and maintaining it during and following fabrication.

•

**Elevated Temperature Corrosion** investigations reported by F. H. Beck and M. G. Fontana in their article "Corrosion by Aqueous Solutions at Elevated Temperatures and Pressures," has been reprinted from CORROSION'S August, 1953 issue by Alloy Casting Institute, 32 Third Ave., Mineola, N. Y. Copies of the reprint are available on request.

•

**An Introduction to Clad Metals,** a 24-page brochure was published recently by the Superior Steel Corp., Carnegie, Pa. Headings include: General Introduction, Definition of Clad Metals, Principles of Bonding, Characteristics of Clad Metals, Methods of Cladding and Applications. The illustrated booklet shows the basic equipment and processes used in the varied cladding methods of the past, as well as those now in production use.

•

**Facts About Silicon Carbide,** a 58-page mimeographed booklet gives the facts of the discovery and occurence, the properties and applications of silicon carbide, most of which are as an abrasive and heat resistant material. The booklet states silicon carbide resists corrosion. It is published by the Carborundum Co., Niagara Falls, N. Y.

•

**Dow Corning Corp.,** Midland, Mich., is publisher of a 5-page loose leaf summary of the properties of Silicone-Based Protective Coatings. The publication says that silicone finishes may be divided into three categories by vehicle content: 100 percent silicone, silicone-alkyd, and modified silicone. The first group has high temperature and corrosion resistance; the second group better film properties, adhesion and hardness and the third group combines air drying with an unusual degree of weather resistance.

•

**Carpenter Steel Co.,** marked the opening in October of a new mill-branch warehouse and office in Milwaukee, Wis., at 4152 N. 35th St. General offices for the firm are in Reading, Pa.

•

**Rochester Manufacturing Co.,** 100 Rockwood St., Rochester 10, N. Y., has announced the development of a straight form industrial thermometer. All external parts are of stainless steel and surfaces are all smooth, corrosion-resistant and non-contaminating. The thermometer has many applications in the chemical, petroleum, food, drug and other industries, the firm states. Features are: An external recalibration device, an oscillation-dampening device, and temperature range from —90 to 1000 degrees F, which covers all standard industrial temperature ranges.

•

**Cooper Alloy Foundry Co.,** Hillside, N. J. has put on the market a new stainless steel valve designed especially to meet requirements of the food, chemical and related industries. Features of the valve are a rugged, compact shell cast body; guided precision cast disc which is made of a high hardness, gall and corrosion resistant alloy; union bonnet; inside screw; nonrising stem valve and highly polished, dirt resistant surface and appearance.

•

**American Chemical Paint Co.,** Ambler, Pa., has published a short, informative folder on its many products. Various metals of construction are listed along with Chemical Paint Co.'s product and what the product will do. A wide variety of uses are indicated on a chart which uses different colors to denote different uses to which the paints and chemicals are put.

•

**The Carpenter Steel Co.,** Reading, Pa., has announced that lifting controls on nickel has freed two of the firm's well known, multiple-purpose chrome-nickel alloy steels for non-defense uses. The steels, identified as Carpenter No. 158 and No. 5-137 alloys are designed to handle 95 percent of all alloy jobs.

•

**Union Carbide & Carbon Corp.,** 30 E. 42nd St., N. Y., N. Y., has recently published the 1954 edition of the 20-page booklet, "Physical Properties of Synthetic Organic Chemicals." For easy reference, the chemicals are arranged by family groups. Condensed data on applications are presented and physical properties are given in tabular form. Free copies may be obtained by writing for "PPSOC" Booklet F-6136.

•

**Porous Plastic Filter Co.,** Glen Cove, N. Y., one of the Pall Filtration Companies, is manufacturer of a compact in-line filter for highly corrosive materials such as fuming nitric acid, hydrogen peroxide and hydrochloric acid. In addition to being resistant to all common acids and gases in all concentrations, the filter will remove all particles larger than five microns in liquid filtration and much finer particles in gas filtration, the company asserts.

•

**The Insul-Mastic Corp. of America,** 1141 Oliver Bldg., Pittsburgh, Pa., will market Insul-Mastic coatings in the Memphis, Tenn., area through the M. H. Ellis Co. of Memphis. The Ellis Co. will use the coatings for corrosion preventive applications to industrial equipment, and for waterproofing buildings, using a decorative finish of colored stone granules. Robert Lear and Son, a Louisville, Ky., firm is representing Insul-Mastic in that area.

•

**North American Philips Co.,** through its Research & Control Instruments Div., 750 S. Fulton Ave., Mount Vernon, N. Y., is marketing an electron microscope with half the power and at half the cost of the firm's large electron microscope. The firm also makes an emmission microscope designed especially for metallurgical studies of metals and various metal oxides during heating.

•

**Delrac Corp.,** Watertown, N. Y., is maker of a new product, "New Delrac

(Continued on Page 28)

CORROSION RECTIFYING CO.

CATHODIC PROTECTION

- SURVEYS
- DESIGNS
- INSTALLATION
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CORROSION RECTIFYING CO.

## NEW PRODUCTS

(Continued from Page 27)

Coating" which the firm says penetrates, seals and waterproofs concrete, mortar, brick, steel and wood, preventing moisture penetration and fungus attack on wood, and rusting of iron and steel. Applied to concrete, Delrac Coating prevents powdering, dusting and fluorescence.

●

**R. M. Hollingshead, Corp.,** Camden, N. J. announces discovery of "QAI," a new inhibitor permitting packaging in metal containers for the first time of quaternary ammonium compounds. The compounds are widely used in production of cationic disinfectants. The new inhibitor is said to be water soluble and to not interfere with the end purpose of the product.

●

**"Protection With Parlon,"** published by the Hercules Powder Co., lists case histories on the performance of the chlorinated rubber product made by the Hercules Powder Co., Cellulose Products Dept., Wilmington 99, Dela. Details in addition to the basic facts described in the booklet can be obtained by writing the factory.

●

**E. I. du Pont de Nemours & Co.,** Inc., Wilmington, Del., has published the fourth in a series telling how the rubber industry runs its tests and what the tests mean to engineers and designers of rubber parts. The booklet is titled. The Language of Rubber, Part IV, Permanent Set, Stress and Strain Relaxation. The brochure gives case histories of the performance of neoprene.

●

**Fenwal Inc.,** Ashland, Mass., manufactures a series of Thermoswitch thermostats, completely enclosed in a plastic sleeve for severe humidity and corrosion service. The thermostat unit may be immersed in most strong and weak acids, alkalis and salts without ill effect. It can be used for temperature control or overheat detection for such applications as plating baths, pickling baths, humidity and corrosion testing chambers.

●

**Indox,** a new permanent magnet which is non-metallic and of non-organic material is being made by The Indiana Steel Products Co., Valparaiso, Ind. The magnet is not an electrical conductor.

●

**National Carbon Co.,** a Division of Union Carbide and Carbon Corp., 30 E. 42nd St., New York, N. Y., has announced a new series of "Karbate" impervious graphite centrifugal pump sizes and types. The new Type C and Type F pumps are for severe corrosive conditions and wherever pumping conditions are corrosive to ordinary iron and steel, for instance the handling of brines and sea water.

●

**Cast Optics Corp.,** Riverside, Conn., has published a brochure on its optically clear rigid plastic sheets. The material is comparable to polished plate glass in lustre, smoothness and chemical resistance, is immune to attack by all solvents the company claims. In resistance to wear, abrasion and weathering, CR-39 approximates polished plate glass, but is much superior on impact resistance.

**Alpha Metals, Inc.,** Box 34, Bergen Station, Jersey City, N. J., is marketing a new product, Cen-Tri-Core Energized Rosin Filled Solder. The solder consists of a solder wire coated with rosin over which is formed the outer solder sleeve. This construction assures continuity of flux the firm states.

●

**Titeflex, Inc.,** 500 Frelinghuysen Ave., Newark, N. J., makes a special type of metal expansion bellows to convey gas and liquids. Text and diagrams explain the welded-diaphragm construction of the bellows and point out how this results in a bellows especially able to withstand high temperature, vibration and corrosion.

●

**The American Metaseal Manufacturing Corp.,** West New York, N. J., is marketing a compact "packaged" system for impregnation of porous metals based on polyester resins and a vacuum pressure cycle. The impregnant resists a wide variety of chemicals, solvents, fuels and lubricants, including acids, alcohol, gasoline and kerosene, caustics, printing inks, salt water, steam and cleaning solutions. Applications include pump assemblies, steam and water pipes, refrigeration units, aircraft parts, valve bodies, pressure lines, automotive fittings, spraying equipment and optical units.

●

**Branson Instruments, Inc.,** 430 Fairfield Ave., Stamford, Conn., has developed a new series of ½-inch diameter crystal transducers, or "probes" for ultrasonic thickness gaging with the firm's Audigage Thickness Testers. Sharply-tapering sections, compound curvatures and other unusual conformations of metal parts can now be measured with the ultrasonic instrument whereas before they could not. "Audigage" instruments measure from one side, the thickness of metals and many other homogeneous materials and are used in inspecting ship hulls, tanks, piping and other pressure vessels accessible from only one side and subject to corrosion.

●

**The Minnesota Rubber and Gasket Co.,** 3630 Wooddale Ave., Minneapolis, Minn., has developed a process for bonding Buna N and neoprene rubbers to white metals, including aluminum and to nylon. For more information, write Dept. KP.

●

**The V. D. Anderson Co.,** 1935 W. 96th St., Cleveland, Ohio, has developed a new float trap for draining corrosive liquids from air, gas and steam confined in piping systems and equipment. The trap is made of stainless steel. Chief applications for the float trap are in the chemical, petro-chemical, refining, natural gasoline, textile, paper-making and food industries.

●

**Atlas Mineral Products Co.,** Mertztown, Pa., has published a plastic bound booklet on the firm's products. The booklet includes reprints of articles from technical magazines, a large section of technical bulletins, illustrated advertisements, selection and application data on plastic pipe, plastics equipment reference sheet and a section on Atlas Corrosion-Proof Cements.

●

**Minneapolis-Honeywell** Regulator Co., Industrial Division, Wayne and Windrim Aves., Philadelphia, Pa., has developed a new line of diaphragm motor control valves, designated "Series 800." The new valve was designed for use with wide-band, proportional control instruments widely used in industry.

●

**Amercoat Corp.,** 4809 Firestone Blvd., South Gate, Calif., is introducing its new sprayable and brushable zinc coating, Dimetcote No. 3, for protection of steel against atmospheric exposures, including corrosive sea atmospheres. The coating is intended also for immersion in water and salt water. The coating weighs 29.6 pounds per gallon, of which 23 pounds is metallic zinc.

●

**Reilly Tar & Chemical Corp.,** 1615 Merchants Bank Bldg., Indianapolis, Ind., has produced a new slide rule coal tar base enamel quantity calculator which gives estimates for quantities of enamel required in pounds per thousand feet and gallons per mile on two grades of Primer. It also gives estimates for coupling compounds required for mechanical couplings on pipe of normal size from 2 inches through 48 inches. The slide rule may be obtained by writing for it.

●

**Bio-Rad Laboratories,** 800 Delaware St., Berkeley 9, Calif., is marketing ion exchange resins which are pre-processed to make them suitable for chemical, medical and physical laboratory applications. Designed to provide a source of pure ready-to-use resins with known properties, this new grade of material will eliminate the resin as an experimental variable.

●

**Societe Des Fonderies de Pont-a-Mousson,** Nancy, France, will produce glass-fibre reinforced plastic pipe under license from Reflin Co., Los Angeles, Calif. The pipe is resistant to rust, chemical attack, electrolytic action and other factors causing deterioration. Pipe diameters up to 10 inches are available. Working pressure is 200 psi and bursting pressure, 1000 psi. Standard fittings and simple tools are used to join the pipe.

●

**American Chemical Paint Company's** Detroit, Mich., office's new address is 10225 W. McNichols Rd., Detroit.

●

**Bakelite Company,** a division of Union Carbide and Carbon Corp., has developed a new cellular polyethylene with half the weight and a dielectric constant about one-half that of regular polyethylene. The new material has been used successfully to insulate ultra-high frequency television lead-in wires. The material has extremely low dielectric constant, excellent power factor, good dielectric strength and high resistance to water penetration, according to company spokesmen. Bakelite has also published a folder: Bakelite Resin Coatings for General Industry. The folder cites actual uses of the coatings. Because of excellent flexibility, the coatings can be applied to flat metal before it is formed into beer and syrup cans. It can withstand the lactic acid and high pasteurizing temperatures in dairies. Other uses are described.

●

**The Master Enterprise Corp.** of America, Boulder Bldg., Tulsa, Okla., has designed a new coupling especially to

(Continued on Page 29)

## NEW PRODUCTS

(Continued from Page 28)

simplify the connecting of tubes or pipes in any size range and for any purposes. No threading, flares, ferrels or tools of any kind are required. Couplings can be made fast and by inexperienced help, the firm states.

•

**The United States Stoneware Co.,** Akron 9, Ohio, has printed a brief description of impermeable Kel-F Welded Linings. Kel-F membranes are a composite of polyethylene and vinyl layers with a Kel-F insert. The insert provides the protection. The other two parts of the insert unit protect it from mechanical damage.

•

**Capitam WS-11,** is the trade name for a new acid inhibitor being marketed by the Capitol Chemical Co., 3255 Prospect Ave., N. W., Washington, D. C. Among the uses for the product are acid cleaning and pickling operations and acidizing oil wells. Included in the mailing piece published by the firm is a graph showing relative corrosion loss of mild steel using Capitam WS-11.

•

**Arthur S. LaPine and Company,** 6001 S. Knox Ave., Chicago 29, Ill., manufacture a polyethylene sink unit for use in laboratories. The unit consists of: stopper, high level drain, strainer, locknut, plug, trap and outlet union. It is dent-proof, break-proof, chemical resistant and may be installed easily on any laboratory sink.

•

**Babcock & Wilcox Co.,** Tubular Products Div., Beaver Falls, Pa., has issued a new data card, designed to be of assistance in the selection, application and installation of carbon, alloy and stainless steel pipe. Known as TDC 138 A, the data card contains information on dimensions, weights, specifications, grades and analyses of seamless and welded carbon, alloy and stainless steel pipe.

•

**Crawford Fitting Co.,** 884 E 140th St., Cleveland 10, Ohio, has added a new line of small instrument air valves to its other items. Valves are equipped with Swagelok ends, and are made in brass, aluminum, steel and stainless steel.

•

**Emjay Maintenance Engineers,** 327 Union Ave., Rutherford, N. J., have developed Kolmetal, a mixture of finely pulverized aluminum in a plastic base. Two applications of the product with a 4-hour drying interval between them, air hardens to a plastic bonded aluminum surface which can be polished, ground, drilled or bent to a 45 degree angle without chipping or cracking. Laboratory tests show excellent resistance to atmospheric and sea water corrosion, retention of finish and firm adhesion over a wide range of temperatures. It is completely inert to a long list of foods and other liquids, the company says.

•

**The Cooper Alloy Foundry Co.,** Hillside, N. J., in its publication, C-A Newscast, lists a cast alloy reference sheet which gives the features of the corrosion resistance of Cooper Alloy 175 (Type 18-8). The mechanical and physical properties of the alloy are given also.


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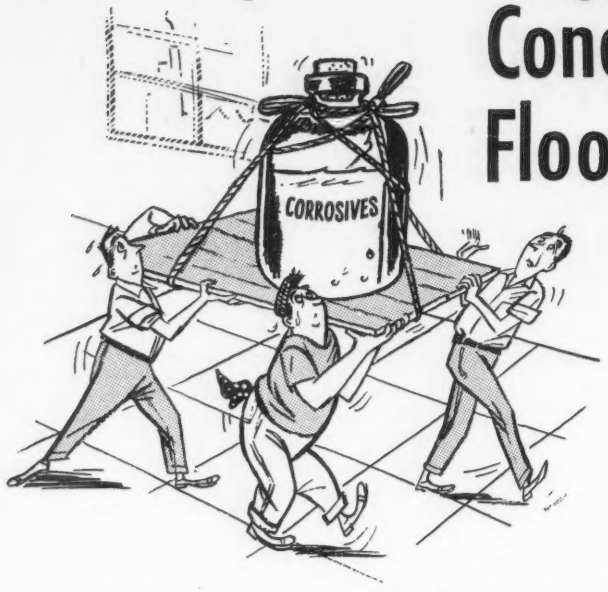


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## PERSONALS

**Nat Armel,** a veteran of nearly 43 years of service with The Glidden Co. has retired as sales manager of the company's Nubian Industrial Division in Chicago. He was succeeded by **Caroll O. Hutchinson,** former assistant sales manager and technical service director at Nubian.

•

**Neil Petersen,** for the past eight years Parker Rust Proof Company Technical Representative in the Detroit area, has been transferred to the West Coast to serve the growing needs of this region.

•

**Dr. George Gerard** has been appointed assistant director of the Research Division of New York University's College of Engineering, according to an announcement by **Dr. Harold K. Work,** director of the division. The research division, with a staff of 405, has an annual operating rate of more than $2,000,000 in research sponsored by industry and government.

•

**George S. Howard,** the General Paint Corp., is being placed in charge of the company's Airborn Finishes Dept. in the Middle West. He will move from the firm's Houston office to Tulsa, Okla. to set up the offices. **Harold Thurmond** will replace Mr. Howard in Houston.

•

**C. H. Nichols** has been appointed head of the chemical engineering process design division of the Engineering Corp. of America, Westfield, N. J. The division offers consulting engineering services to chemical and industrial plants in connection with the development and design of new process units and equipment and specializes in industrial waste treatment and water and air pollution abatement.

•

**Robert E. Halloran** has received the appointment to the newly-created position of manager of mechanical sales for the Tubular Products Division of the Babcock & Wilcox Co., Beaver Falls, Pa. He will supervise the sales of mechanical tubular products. **James S. Anderson** has been appointed general sales manager of the Tubular Products Division. He will direct the sales of carbon, alloy and stainless steel tubular products. Death of a vice president and director of the firm has been announced. **James H. King,** Scarsdale, N. Y., died in November.

•

**Col. Willard F. Rockwell,** chairman of the board of Rockwell Manufacturing Co. was one of four Pittsburgh industrialists re-elected to the National Industrial Conference Board for a one-year term. The conference board was founded in 1916 for the purpose of business and industrial fact-finding through scientific research and is a non-profit organization supported by more than 3300 subscribing associates including business and trade associations, government bureaus, labor unions, universities and other groups.

•

**Leo Bernard Farrell** has become office and plant manager of Seaporcel Pacific, Inc., Long Beach, Cal., an affiliate of Seaporcel Metals, Inc., Long Island, N. Y. The firms make and sell porcelain enamel.

# Corrosion Abstracts


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## 1. GENERAL

### 1.5 Directories of Material

1.5, 5.3.2, 5.3.4, 6.2.3

**Metallizing for Corrosion Prevention.** G. C. CLOSE. *Products Finishing*, **16**, No. 3, 58-65 (1952) Apr.

Finishing with sprayed metal is popular in conjunction with structural steel and sheet metal products that require a high degree of protection during service life. Zinc and aluminum are the most common spray metals. A combination of sprayed metal, primer and outer organic coating offers one of the best protective coating combinations for steel. Sand or grit-blasting is most often used to prepare surfaces prior to application of the coating, and metallizing should be accomplished as soon as possible after blasting to prevent surface oxidation or rusting. Tables give recommended coatings for salt, industrial and rural atmospheres and for immersion in fresh and sea water. A photograph shows the spraying of a ship's water tank cask with corrosion resistant Monel metal.—INCO. 5390

1.5, 6.1

**Properties of Chemical Engineering Engineering Materials of Construction.** C. S. GROVE, JR., J. L. VODONIK, R. S. CASEY, L. F. YNTEMA, AND W. R. BEKEBREDE. *Ind. and Eng. Chem.*, **44**, 2371-2380 (1952) Oct.

Consists of tabulated information on synthetic fibers and less common metals.


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Neither NACE nor the sources listed below furnish reprint copies.

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

AWWA—Journal, American Water Works Association, Amer. Water Works Asoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italian, Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thysen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

Coverage of latter is limited to a supplement to 1950's table and deals with molybdenum. 21 references.—BTR. 5469

1.5, 6.2.1

**Improvements in the Development of Corrosion Resisting Materials.** (General Survey). Part I. Iron and Steel. (In German). ERICH FRANKE. *Werkstoffe u. Korrosion,* **3,** 265-274 (1952) July.

Based on the most important relevant publications of 1950, a survey is given of the corrosion behavior of carbon steels, low and high-alloy stainless steels, iron-silicon alloys, and cast iron. Substitution of titanium for niobium in stabilized 18-8 stainless steels. 168 references.—MR. 5442

1.5, 6.4.2

**Aluminum Alloys.** HARRY W. FRITTS. *Ind. and Eng. Chem.,* **44,** 2289-2292 (1952) Oct.

Annual construction-materials review. Reviews a number of new applications in chemical and petrochemical industries and gives additional information on resistance to corrosion of aluminum alloys by a number of chemicals. 76 references.—BTR. 5436

## 1.6 Books

1.6, 1.3, 6.5

**A.S.M. Review of Metal Literature.** Vol. 8, 1951. Am. Soc. Metals, 7301 Euclid Avenue, Cleveland 3, Ohio. Book, 1952. 9 x 6 inches, 884 pp., $15.00.

An annotated survey of articles and technical papers appearing in the engineering, scientific, and industrial journals and books, here and abroad, received in the Library of Battelle Memorial Institute, Columbus, Ohio.—MA. 5290

1.6, 8.8.1, 8.4.3

**An Introduction to the Study of Metallic Corrosion in the Chemical and Petroleum Industries.** (In French). M. BALLAY, J. BENARD, G. CHAUDRON, J. DUFLOT, P. LACOMBE, AND A. PORTEVIN. Book, 219 pp., 1952. Paris (5e): Societe d'Enseignement Superieur, 99 Boulevard St. Michel.

This book is a record of lectures and practical work which formed the basis of the week's course on corrosion phenomena. It is published with the approval of the Institut Francais du Petrole. The first lecture consists of a general discussion on the principles of corrosion and on the protection of metals, the second with the relationship between corrosion and surface condition, and the third with corrosion testing. Then follow lectures on chemical and electrochemical corrosion, intercrystalline corrosion and stress-corrosion, and on the application of the electrochemical theory to the prevention of corrosion. One lecture is devoted to the pickling of iron and steel, and there are others on the corrosion of metals and alloys by gases at elevated temperatures. The resistance of nickel and its alloys to corrosion is dealt with separately, and so is the use of stainless steels in the petroleum industry. A series of practical exercises designed to illustrate the principles of corrosion is included. The book forms a very useful introduction to the study of corrosion for those engaged in the petroleum and the chemical industries.—MA. 5367

## 1.7 Organized Studies of Corrosion

1.7.2, 2.2.1, 5.4.5

**Tomorrow's Products Tested Today.** W. W. SMITH. *Org. Finishing,* **12,** No. 4, 13-16 (1951) April.

Description of exposure tests at South Florida Test Service located at Miami, Florida. Panels 4 inch x 12 inch or 6 inch x 12 inch of either wood or metal are tested for paint exposure to inland, salt atmospheric, total immersion and tidewater, and under glass exposure.—INCO. 5064

1.7.1, 6.2.1

**Report of Committee A-5 on Corrosion of Iron and Steel.** *Am. Soc. Testing Materials,* Preprint No. 4, 1952, 17 pp.

Recommendations for revisions in standards, specifications, and test methods. Extensive tabular data on atmospheric corrosion of 22-gage copper-bearing, non-copper-bearing, and galvanized, black, corrugated sheet metal. Specification revisions for zinc-coated sheet steel.—BTR. 5453

1.7.1, 6.2.3, 6.2.4, 6.2.5

**Report of Committee A-1 on Steel.** *Am. Soc. Testing Materials.* Preprint No. 2, 1952, 45 pp.

Recommendations affecting standards and specifications. Mechanical testing of structural steel. Specifications for heavy-walled carbon and low-alloy steel castings for steam turbines; for 5%-chromium, 0.5%-molybdenum steel plates for boilers and pressure vessels; for alloy-steel bars for nitriding; for electric-fusion welded austenitic chromium-nickel alloy-steel pipe for high-temperature service; and for carbon and alloy-steel forgings for rings for reduction gears.—BTR. 5451

1.7.1, 6.2.5, 2.2.2

**Report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.** Paper before ASTM, 55th Ann. Mtg., N. Y., June 23-27, 1952. Am. Soc. Testing Materials, Preprint No. 7, 1952, 4 pp.

Subcommittee IV on methods of corrosion, under the chairmanship of Mr. F. L. LaQue, is making an effort to get the atmospheric corrosion test program under way. It was decided to include in the program the 18% chromium-4% nickel-4% manganese steel that had been dropped previously. The present effort is an exploration of the immediate availability of the large amount of specimen material that will be required from the several producers. Table.—INCO. 5454

# 2. TESTING

## 2.1 General

2.1.1

**Corrosion: Methods of Presenting Corrosion Data.** M. G. FONTANA. *Ind. and Eng. Chem.,* **44,** No. 5, 103A-104A (1952) May.

Several methods of presenting corrosion data are briefly discussed in support of the suggestions that corrosion information should be as quantitative as possible. The schemes are mainly graphical and the author favors mils per year as the expression which might be standardized.—RPI. 5477

2.1.2, 1.3, 1.7.1

**Corrosion Testing.** FRANCIS L. LAQUE. *Proc. Am. Soc. Testing Materials,* **51,** 495-582 (1951).

Twenty-fifth Edgar Marburg Lecture. An excellent and comprehensive review of corrosion-testing methods, which clearly indicates the usefulness and limitations of many commonly used tests. Many examples are given of the relationship between corrosion in laboratory tests and behavior in natural environments and in practice. Some of these results are published for the first time. Emphasis is given to tests organized by various A.S.T.M. subcommittees. The following are some of the topics discussed: the behavior of steels exposed to the atmosphere and in various accelerated tests the effect of position of specimen on atmospheric corrosion of steel, the effect of impurities and alloying elements on the atmospheric corrosion of steel, the determination of the corrosivity of atmospheres with particular reference to the behavior of zinc and steel, the effect of various factors on the corrosion of steel in sea-water and other natural waters, the corrosion of partially immersed steel piling, the corrosion of immersed dissimilar metal couples and the significance of electrode-potential measurements, the significance of polarization curves, corrosion of dissimilar metal couples in the atmosphere, salt-spray tests and the testing of protective metal coatings on steel, humidity tests, laboratory tests for immersed specimens, including rotor tests and jet-impingement tests, the nitric acid test for testing the susceptibility of stainless steels to intergranular attack, testing on the plant, and the testing of paints. 95 references.—MA. 4989

## 2.2 On Location Tests

2.2.2, 5.4.5, 6.6.11

**Preparation of Varnish Panels for Exterior Exposure (Tests).** Federation of Paint and Varnish Production Clubs and American Society for Testing Materials. *Official Digest Federation Paint and Varnish Production Clubs,* No. 327, 219-220, 1952.

Durability tests on six varnishes by four operators over six months exposure are reported. The varnishes are applied to maple panels in three coats, sanding between coats, and were exposed at 45° facing south. They were arranged in essentially the same order of merit by all operators, indicating that the test procedure was satisfactory.—RPI. 5352

2.2.2, 6.5

**The Atmospheric Corrosion of Metals at Various Sites in Nigeria; Comprehensive Report on Trials From 1948 to 1952.** H. R. AMBLER. Gt. Brit. Tropical Testing Establishment, Port Harcourt, Nigeria, Report No. 216, Aug. 1952. 61 pp.

The atmospheric corrosion of mild steel and, to a lesser extent, of brass, aluminum, iron, and zinc was studied for 4 years under a variety of tropical conditions. The major variant was the distance from the sea, i.e., the salinity and pollution of the air. Other variants included vertical height, panel orientation, exclusion of solid matter, protection from rain, length of exposure, and the seasonal variations of the interrelated factors of temperature, humidity, rain, solar radiation, wind speed, wind direction, and dew deposition.

Atmospheric corrosion of mild steel

on a tropical surf beach can be as much as 7 g. per 100 sq. cm. per month. In similar humidities, with no salinity or industrial pollution, it is of the order of 0.07 g. In the absence of surf, proximity to the sea does not cause heavy corrosion. The effect of surf falls off rapidly with the distance; beyond about half a mile the corrosion is relatively small. The decrease is greatest for zinc, smaller for iron and steel, and least for brass and aluminum.

The threshold value of salt concentration in the air at which heavy corrosion occurs is of the order of 1 mg. per cu. meter. There is some evidence that increases above 3 mg. would not greatly increase corrosion. The airborne salt on a surf beach is predominantly sodium chloride. Small pollution by the products of coal fires greatly increases the corrosion of steel. The proportionate effect on zinc is much less.

There is more corrosion in the wet season than in the dry season, the effect being less on a beach than in a rain forest inland. Protection from rain, over a period up to 3 months does not reduce corrosion appreciably, and may increase it. The daily deposition of dew appears to have a pronounced effect. Daily spraying with 1% solutions of sodium chloride or sulfate causes corrosion of the same order as on a surf beach, chloride being the more damaging. The exclusion of solid matter by a muslin screen greatly reduces corrosion both on a surf beach and in an area of industrial pollution.—PDA. 5396

**2.2.5, 2.3.2, 2.3.7**

**Second Report of the Methods of Testing (Corrosion) Sub-Committee.** British Iron and Steel Research Assoc. *J. Iron Steel Inst.* (London), **171**, Pt. 3, 255-272 (1952).

A series of tests has been carried out in a number of laboratories on the lines proposed in the First Report of the Subcommittee. The results of outdoor tests have confirmed that the A.R.E. salt-droplet test gives a reasonable indication of the service performance of protective coatings. The reproducibility of the breakdown of protective schemes at scratches inflicted according to Provisional British Standard 1391 (1947) has proved adequate. Although satisfactory agreement has been found between the behavior of coatings at the impact dome when subjected to both the A.R.E. test and outdoor exposure, observations made will not be of equal significance with those made at the scratches unless the severity of the blow is increased or the permissible spread of failure is reduced. A new laboratory test, developed by the Chemical Research Laboratory (Teddington), has given fair correlation with the results of outdoor exposure tests and is satisfactorily reproducible in different laboratories. Interim results, for five years' exposure, are presented for the original field test. In an appendix, preliminary suggestions are made for the removal of corrosion products from mild-steel specimens carrying protective schemes of metallic coatings, with or without paint.—RPI. 5371

**2.2.6, 3.3.4, 7.2**

**Investigations on Underground Corrosion.** K. R. Butlin, W. H. J. Vernon, and L. C. Whiskin. Iron Steel Inst. Special Rep., No. 45, 29-38 (1952).

Fundamental studies on sulfate-reducing bacteria, and investigations of the effects of these bacteria on iron in anaerobic conditions are described. Details of field tests on bare and protected buried iron pipes are given. Specimens of copper, lead, and galvanized steel pipe are included in tests now in progress.—MA. 5383

## 2.3 Laboratory Methods and Tests

**2.3.2, 2.2.2**

**Difficulties Encountered in Open-Air Exposure Testing and Comparison Between Several Methods of Accelerated Weathering.** M. D. Bermane. *Chemistry and Industry*, No. 16, 354 (1952).

In testing a wide range of compositions, it was found that although type of breakdown varied according to the exposure site, the relative order of merit was the same. The correlation between four methods of accelerated testing was investigated.—RPI. 5306

**2.3.2, 2.4.2**

**Accelerated Weathering Test.** R. S. Dantuma. Verfinstituut Circ. (Holland). Circular No. 72, 1952.

A description of 20 years' experience in developing accelerated weathering apparatus. The present apparatus gives reasonable but not fully satisfactory correlation with natural weathering. It involves 4-8 hour periods of exposure to ultra-violet light and water spray and cooling of the undersides of test panels during irradiation.—ZDA. 5468

**2.3.2, 2.5, 6.2.2, 6.3.19**

**Researches on the Salt Spray Test.** (In Italian). G. Bianchi. *Metallurgia Italiana*, **44**, Nos. 8/9, 330-335 (1952) Aug., Sept.

Influence of test conditions and form of test pieces on loss-of-weight experiments on iron and zinc. Results are used as basis of recommendations for method of carrying out the test. Mechanism of corrosion process is discussed.—INCO. 5311

**2.3.2, 5.3.2, 5.4.5, 6.2.1**

**Protection of Ferrous Surfaces Against Corrosion.** E. Antinori. *Gas Oil Power*, **47**, 112 (1952); *J. Brit. Shipbuilding Res. Assoc.*, **7**, No. 6, 352 (1952).

Tests have been carried out to determine the behavior in salt spray of a number of coatings used to protect metal surfaces from corrosion. The coatings were of two types, organic coatings and non-electric nickel plating. The most satisfactory was found to be a hot-dip type of strippable plastic coating. The nickel-plated specimens showed good results in proportion to the thickness of the deposit on each. The use of inhibitors to reduce the corrosion of ferrous surfaces in contact with cooling water was studied, the best mixture being equal parts of potassium chromate and sodium carbonate.—RPI. 5399

**2.3.2, 5.4.5, 8.1,2**

**Weathering and Durability of Building Materials.** R. J. Schaffer. Building Res. Congress, Div. 2, 14-21 **1951.**

The results of investigations into the weathering qualities of building materials carried out in the United Kingdom during the last 150 years are reviewed. Accelerated tests (including accelerated weathering tests for paints) are discussed. 31 references.—RPI. 4975


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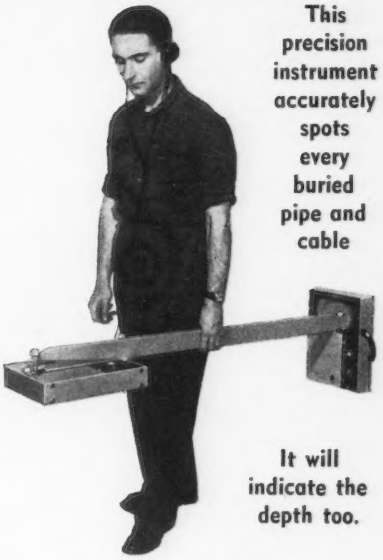

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2.3.4, 2.6, 5.9.2

**Proposed Method of Total Immersion Corrosion Test for Soak Tank Metal Cleaners.** Paper before ASTM, 55th Ann. Mtg., N. Y., June 23-27, 1952. ASTM Report of Committee D-12 on Soaps and Other Detergents, Preprint No. 41, 12-16.

The test is intended as a means of determining the corrosive effects of soak tank metal cleaners on all metals other than aluminum and its alloys, under conditions of total immersion, by quantitative measurement of weight change or by qualitative visual determination of change. Supplements I and II give methods for electrolytic cleaning of corrosion test specimens after exposure and chemical methods for cleaning corroded specimens without use of electric current. A table giving the weight losses for brass, bronze, nickel and nickel alloys and stainless steel subjected to electrolytic cleaning treatment is included.—INCO. 5310

2.3.5, 3.8.2

**Interpretation of Potentiometric Measurements by Means of Polarization Curves.** J. COURSIER. *Anal. Chim. Acta,* **7,** 74-77 (1952) July.

Experimental results of potentiometric determinations are explained by means of polarization curves. Explanations are given of the following phenomena: electrical activity of ions and its absence; nature of electrode; time required to establish a stable potential; significance of limiting potentials and concentrations; influence of oxygen on measured potentials and on limit of electrical activity of the oxidants; signficance of the "irreversible" potentials; formulas giving potentials in the presence of oxygen; and value of removing oxygen from solutions for potentiometric determinations. 12 references.—BTR. 5409

2.3.5, 7.2, 3.6.7

**Surface Potential Surveying of Bare Underground Lines.** T. L. CANFIELD. *Oil Gas J.,* **51,** No. 23, 330, 332 (1952) Oct. 13.

The surface potential method of surveying current flow in bare underground pipe lines is described and illustrated. Difference in potential a between two points on the ground directly above a pipe line and b between a point directly above the line and a point 3 or 4 feet from the line are measured with two copper-copper sulfate half cells. Costs are $75-200/mi. 5422

2.3.5, 8.9.3, 2.4.2

**Photoelectric Recorder Locates Pipe Corrosion.** *Elec. World,* **138,** No. 2, 160 (1952) July 14.

A portable photoelectric instrument was used to make electrolysis surveys of a 94 mile water pipe of the East Bay Municipal Utility District in California. The corroded regions were indicated by a drop in current. This apparatus is considered to be better than potentiometer instruments. 5478

2.3.6

**Visual and Optical Evaluation of Metal Surfaces.** H. THIELSCH. *Metal Finishing,* **49,** No. 5, 54-61 (1951).

A great variety of instruments have been developed for the purpose of defining or analyzing the contours or geometry of surfaces. It is important to realize that, because of the diversities of the techniques and applications of the various instruments, the same surface characteristics are not analyzed by all instruments alike. Each major method has its own individual merits. Thus, comparison among the various optical procedures is often difficult and may even be misleading. In many surface studies several different methods may be used which complement each other. —EL. 5131

2.3.6, 3.2.3, 3.7.4

**Structure of Oxide Replica for Electron Microscopy.** SHIGETO YAMAGUCHI. *J. Applied Phys.,* **22,** 1295-1296 (1951) Oct.

The oxide films formed on metals and able to reprint faithfully their surface forms are called "structureless." Shows that the "structureless" oxide film formed on the etched surface or iron single crystals is composed of oriented crystals of small size.—BLR. 5243

2.3.7

**Erosion-Corrosion Resistance of Metals.** MARS G. FONTANA. *Ind. and Eng. Chem.,* **44,** No. 9, 101A-4A (1952) Sept.

High velocities, solids in suspension, impingement, turbulence, and other similar conditions often cause greatly increased attack as compared to static or essentially static environments. Several methods and techniques for studying this erosion-corrosion of metals and alloys are reviewed, the apparatus being illustrated.—NSA. 5479

2.3.7, 2.4.2, 4.6.2

**Corrosivity Test of Industrial Water** (USBM Embrittlement Detector Method). Paper before ASTM, 55th Ann. Mtg., N. Y., June 23-27, 1952. Am. Soc. Testing Materials, Preprint No. 48, 12-19, 1952, June.

This method covers the apparatus and procedure for determining the embrittling or non-embrittling characteristics of the water in an operating boiler. For embrittlement cracking of the boiler metal to be possible, the boiler water must concentrate a thousand times or more in contact with the metal under high residual or applied tensile stress. In the embrittlement detector, the conditions of concentration and stress are provided by the design of the unit. The term embrittlement cracking in this method is defined as a form of metal failure that occurs in steam boilers at riveted joints and at tube ends, the cracking being predominantly intercrystalline. Definition in accordance with the Standard Definitions of Terms Relating to Industrial Water (ASTM Designation: D 1129), apparatus, test specimens, assembly of specimen and detector, installation of detector, test interval, inspection, and interpretation of results are described. Diagrams are included.—INCO. 5303

2.3.7, 2.4.3

**A Gauge for Testing Metal Coating Thickness Suitable for Use With Paints, Ceramic Coatings, Plastic or Paper.** Finish, **9,** 17 (1952) April.

Thickness of coatings can now be measured within 0.0005 inch accuracy by a new instrument built by the Ryan Development Laboratory and designed by the National Bureau of Standards.—MA. 5460

2.3.9, 5.3.4, 3.2.3

**Some Applications of Interferometry to the Examination of an Electrodeposited Film.** S. TOLANSKY. Paper presented at the Annual Conference of the Electrodepositors' Tech. Soc., Torquay, England, April 13, 1951. *J. Electrodepositors Tech. Soc.,* **27,** Adv. copy No. 6 (1951).

A brief survey covers the principles of the techniques which have been developed, which makes use of multiple-beam interferometry. Specific application is made to metals in general and to electrodeposits in particular. Applications of multiple-beam interferometry are discussed under the headings: study of surface contour: investigation of hardness indentations and measurement of thin film thickness. The application of the general consideration of measurement of a thin film is considered in the examination of an electrodeposit of tin-nickel. A short discussion is given on efforts to find the ratio of coating thickness to indentation depth permissible for a reasonably accurate determination of the hardness of a coating whose thickness has been interferometrically evaluated.—ALL. 5123

2.3.9, 3.8.4, 6.3.13

**A Spectrophotometric Study of the Oxidation of Tantalum.** J. T. WABER, G. E. STURDY, E. M. WISE, AND C. R. TIPTON, JR. Los Alamos Scientific Lab. Mar. 23, 1951, 57 pp.

The air oxidation of tantalum has been studied by newly developed spectrophotometric and microgravimetric methods in the temperature range 220° to 350°C. The resistance of tantalum to oxidation and to thermal cycling of the oxide-covered metal is excellent up to 320°C. Highly adherent scales were formed despite frequent heating and cooling. On the basis of other data not specifically included in this report, tantalum follows a logarithmic rate equation up to approximately 320°C. Above this temperature the rate law may be either parabolic or logarithmic, but an unambiguous choice cannot be made. A comparison of the results obtained by the two methods reveals good agreement. An estimate of the ratio of the true to the apparent surface area is $9.92 \pm 0.07$. The energy of activation for the initial parabolic rates of weight change was found to be 27.2 kcal/g mole which is in excellent agreement with the value of Gulbransen and Andrews. The logarithmic growth laws similarly gave straight lines on an Arrhenius plot. The energy of activation from the microbalance data was 12.57 kcal/g mole, and that from the spectrophotometer was 12 kcal. A high degree of reproducibility for heterogeneous reaction was achieved in this work. The triplicate determinations of surface area ratio were obtained with a probable error of 0.8%, and quadruplicate runs of the parabolic reaction rate constant gave a probable error of 3%.—NSA. 5209

2.3.9

**Radiocobalt Reveals Flaws in Thick Castings.** R. B. STANTON. *Am. Machinist,* **95,** No. 12, 137 (1951) June 11.

A radiographic inspection with radiocobalt is said to be more effective and less expensive than standard methods of using X-rays to locate internal flaws in metal products. This method with radiocobalt can be used on steel parts with thicknesses up to 15 inches.—INCO. 5073

2.3.9, 2.4.3

**The Application of Radioactive Isotopes in Material Testing.** (In German). O. VAUPEL AND N. VON WETTERNECK. *Metall*, **5**, 293-294 (1951) July.

Shows that gamma-rays emitted by synthetic iridium isotopes can be used for X-ray recordings. Experiments were made with different materials, different films, and different instruments. Results reveal that recordings ordinarily fail to show sufficient details, but methods of increasing contrast are discussed.—MR. 5152

2.3.9, 6.3.8, 4.4.2

**X-Ray Study of the Action of Oleic Acid on Lead.** (In French). J. J. TRILLAT AND S. BARBEZAT. *J. Recherches Centre Natl. Recherche Sci.*, No. 16, 18-20 (1951).

Influence of temperature on the above, as well as other factors, was investigated. Includes X-ray diagrams.—BLR. 5175

2.3.9, 2.4.3

**Ultrasonic Testing Today.** H. E. VANVALKENBURG. *Tool Engr.*, **27**, No. 2, 36-38 (1951).

A review of ultrasonic testing literature showed that only over the last five years has this method of inspection become popular and that all methods published were either based on continuous transmission, thickness resonance, or pulse reflection. The basic principles of ultrasonic inspection are discussed, including mechanical phenomena, penetration, convenience of operation, practical signal-to-noise ratio. Potential applications are considered to include study of elastic properties, determination of physical constants, control of metallic operations, and to control product quality.—MA. 5153

2.3.9, 2.3.6, 3.2.3

**Studies of Surface Reactions by Means of Radioactive Tracers.** T. WESTERMARK AND L. G. ERWALL. *Research* (London), **4**, No. 6, 290-292 (1951).

A study is being made of the sorption of ions on the surfaces of solids; the method consists of bringing a plane surface of the solid into contact with a water solution of a radioactive substance of high specific activity, followed by examination of the surface activity by Geiger-Muller counters or by autoradiography. An example of the application to a metallic specimen is given, consisting of photomicrographs of a lead-tin-antimony-copper alloy, one before treatment, and the other, an autoradiograph, after treatment for 20 minutes with a water solution of $^{212}Pb$. Lead-rich areas of the structure and dark areas within the antimony-copper crystals sorbed $^{212}Pb$. A technique of this kind may be useful in attempting to follow surface reactions of the treated metallic surface.—MA. 5145

2.3.9

**Miniature Radiography.** S. L. FRY. *Metal Ind.* (London), **80**, No. 24, 479-480 (1952).

Where the highest results of an X-ray examination are required and cost is not a prime factor, radiography must be used; where information of only local internal defects is required, cost is important, and a permanent record is not necessary, a fluorescent screen can be used. Miniature radiography is intermediate between these two methods, giving a considerable reduction in film cost,


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marked increase of sensitivity over screening, and a permanent record.—MA. 5440

2.3.9

**Changes in Potential of the Dropping-Mercury Electrode During Drop-Formation, and Measurement of Potential in Polarographic Analysis.** W. FURNESS. *Analyst,* **77,** 345-355 (1952) July.

With a Tinsley polarograph, reasonable agreement was found between calculated and observed effects. Difficulties with polarographic cells incorporating a quiet mercury pool to conduct the diffusion current are not always satisfactory; in contact with certain oxy-acids of sulfur, for example, such electrodes may acquire insoluble films, in which case their potential and electrical resistance becomes erratic. These complications are avoided by means of cells having a pair of permanently attached calomel electrodes. 11 references.—BTR. 5446

2.3.9

**Physical and Metallurgical Viewpoints in Ultrasonic Testing of Materials.** (In German). H. J. SEEMANN. *Metall,* **5,** 531-537 (1951) Dec.

Describes the above on the basis of the literature, particularly the problem of scattering and absorption in solid bodies and its connection with the structure of the test pieces. Data are tabulated and charted. 25 references.—BLR. 4955

2.3.9, 2.4.3

**The Non-Destructive Inspection of Materials by Ultrasonic Waves.** M. SANDRARD. *Ingenieurs et Techniciens,* **33,** 205-209 (1951).

Sandrard makes a comparison between the known methods of non-destructive testing. The principles of ultrasonic waves and a survey of their properties are given.—MA. 4991

2.3.9, 2.6

**A Technique for Preparing Beta-Ray Autoradiographs of Metals and Minerals.** A. B. MICHAEL, W. Z. LEAVITT, M. B. BEVER, AND H. R. SPEDDEN. *Journal of Applied Physics* (U.S.A.), **22,** No. 12, 1403-1406 (1951) Dec.

Work was undertaken to develop a technique of beta-ray autoradiography for the study of metals and minerals on a microscale. The unique features of the new technique are the procedure for manipulating the film and the method of examining the finished microautoradiograph. Thin sections of the metal to be examined are prepared by grinding, polishing and etching one surface of the sample. The prepared surface is then cemented with glycol phthalate to a cylinder of plastic which serves as a sample mount. The mounted metallic specimen is machined to a thickness of less than 70 microns followed by grinding on abrasive paper until a thickness of 20 microns is attained. All samples were irradiated in the finished state. Eastman Kodak NTB Stripping Film was used; and for stripping the supporting layer from the backed emulsion and mounting the latter on the specimen, a fixture consisting of a base plate, a guide, a spacer and a cutter was adopted. A square piece of Scotch Tape, having a hole in the center, is placed over the hole in the base plate so that the two holes are in register. A piece of film two inches square is cut and the backed emulsion is then loosened along one edge from the supporting cellulose. The piece is attached to the Scotch Tape with the emulsion side down and the support is stripped off completely. The locating pins in the guide are then inserted in the holes in the base. A ring of double-sided Scotch Tape is placed in a 0.009-in. groove in the plastic specimen mount. The surface of sample and mount is coated with a lacquer and the mount is placed inside the spacer and pressed firmly to contact the stripped film before the lacquer dries. The ring of Scotch Tape provides an immediate bond and fixes the emulsion on the specimen. The spacer is removed and the circular cutter brought down to cut the film at the edge of the mount. The specimen is placed in a desiccator containing phosphorus pentoxide in a light tight box for the chosen exposure time. The processed emulsion is examined under the microscope at magnifications of 50 to 1500 diameters. The number of silver halide grains rendered developable is determined by the radioactivity of the sample, the time of exposure of the emulsion and the energy of the beta-particles emitted by the sample. Photomicrographs are shown and discussed.—ALL. 4987

2.3.9, 2.6, 3.2.3

**The Metallographic Preparation of Porous and Friable Coatings.** D. CAPLAN AND P. E. BEAUBIEN. *Can. J. Technol.,* **30,** 211-213 (1952) July-Aug.

During the metallographic examination of the scale layers on heat-resistant alloys, great difficulty was experienced in preparing polished cross sections because of the tendency of the porous and fragile oxide layers to disintegrate during cutting, mounting, grinding, and polishing. The usual method of mounting in plastic by pressure molding not only crushed the layers but did not permit the supporting plastic to enter into the interstices. Describes a double vacuum-impregnation technique using two liquid plastics which gave satisfactory results. —BTR. 5348

2.3.9, 3.2.3, 3.8.4

**An Interferometric Method for the Determination of the Absorption Coefficients of Metals, with Results for Silver and Aluminum.** (Method of Determining Rate of Growth of Corrosion Layers on Films Exposed to Air). L. G. SCHULZ. *J. Opt. Soc. Amer.,* **41,** No. 12, 1047-1051 (1951) Dec.

Absorption coefficients determined from the change of phase accompanying the reflection of light at normal incidence. An interferometric method is described for studying the rate of growth of corrosion layers on films which have been exposed to air. Silver could be exposed without any apparent corrosion. The oxide layer on aluminum reached a maximum thickness of about 45 angstroms.—BNF. 5002

2.3.9, 4.7

**An Investigation of Electromagnetic Flowmeters.** H. G. ELROD, JR. AND R. R. FOUSE. *Trans. Am. Soc. Mech. Engrs.,* **74,** 589-594 (1952) May.

Use of the above for measurement of the flow of molten corrosive metals in small sizes of conduit appears to possess the greatest number of advantages. The work described was undertaken to acquire further knowledge of the characteristics of these instruments and some experience in their operation.—BTR. 5475

## 2.4 Instrumentation

2.4.2

**Industrial Metal Detector Design.** CURTISS R. SCHAFER. *Electronics,* **24,** 86-91 (1951) Nov.

How to design a metal detector for a specific application. Fundamental principles, basic equations and major design factors. A typical commercial industrial detector. 19 references.—MR. 4974

2.4.3

**International Conference on the Non-Destructive Testing of Materials,** at **Saarbrücken,** Nov. 30-Dec. 2, 1950. H. J. SEEMANN. *Metall,* **5,** Nos. 3/4, 68-69 (1951).

Brief reports on the following papers presented at the meeting: 1. R. Berthold: "Non-Destructive Methods for Measuring the Thickness of Walls and Coatings"; 2. H. Trost: "The Counter-Tube as an Accessory for Testing Materials"; 3. Th. Wuppermann: "Thickness Measurements During the Production of Tinplate"; 4. O. Vaupel: "Experiences of Radiographic Inspection in Berlin and the Eastern Zone of Germany Since 1945"; 5. H. Gerbeaux and M. Evrard: "Experiences in Inspecting Materials with Gamma Radiation"; 6. C. Brachet: "The Use of Irradiated Materials for the Radiological Inspection of Large Objects"; 7. F. Gottfeld: "The Use of Radon and Radioactive Isotopes in England for Non-Destructive Testing"; 8. A. Guinier: "The Role of Fine-Structure Investigations in Non-Destructive Testing"; 9. C. Legrand: "The Investigation of Surface Films by X-Rays and the Details of a Suitable Type of Debye Camera for This Purpose"; 10. H. Möller: "New Possibilities in the Measurement of Stresses by X-Rays, by the Use of Short-Wave Radiation"; 11. J. J. Trillat: "Micrography with Secondary Electrons"; 12. H. J. Seemann: "Physico-Metallurgical Considerations in the Ultrasonic Testing of Materials"; 13. P. Bastien: "Sources of Error in the Ultrasonic Testing of Metallic Materials"; 14. I. Krautkrämer: "A New Ultrasonic Testing Instrument Based on the Impulse-Reflection Principle, and Some Results Obtained with It"; 15. G. A. Homès, J. Ots, and E. Symon: "Belgian Methods of Ultrasonic Testing"; 16. R. Pohlman: "Sources of Error in Acoustic Methods of Testing"; 17. R. Cabarat: "An Acoustic Method for Determining the Elastic Modulus and the Internal Friction of Solids"; 18. J. Jellinghaus: "Magnetic and Electrical Methods of Non-Destructive Testing"; 19. F. Förster: "New Methods of Non-Destructive Testing Based on Magnetic Properties"; 20. H. de Leiris: "Methods of Inspection Based on the Principle of the Milk of Lime Process"; 21. A. Forster: "Methods and Instruments for the Practical Testing of Surfaces"; 22. E. Loeville: "Spectral Analysis as an Accessory in Non-Destructive Testing."—MA. 5394

2.4.3, 3.7.3, 1.6

**Memorandum on Non-Destructive Methods for the Examination of Welds.** Brochure. March, 1952, 63 pp. British Welding Research Association, 29 Park Crescent, London, W.1. 5s.

A survey of available methods: semi-destructive methods (attached test-pieces and weld probing); X-ray and gamma-ray radiography; magnetic methods;

penetrants (e.g., fluorescent dyes); electrical, chemical and acoustical (including ultrasonic) methods, proof testing. Treatment is general rather than confined to individual metals, and the scope and limitations of each method are emphasized. In appendices are tabulated the methods suitable for each joint form, and the types of defect that each method can be expected to reveal. 51 references. —BNF. 5380

## 2.6 Preparation and Cleaning of Specimens

2.6, 2.2.3, 2.1.2

**German Draft Specification DIN 50905 (Sept. 1951): Corrosion Testing-Performance and Evaluation.** W. WIEDERHOLT. *Werkstoffe u. Korrosion,* **2,** No. 9, 334-339 (1951).

Complete details are given of the new draft specification for the techniques to be employed in: 1. the preparation of the specimens and the corrosive media, 2. the performance of the tests, and 3. the evaluation of the results, i.e. determining a. the loss in weight, the surface changes, the depth of attack, and the changes in structure and mechanical properties of the specimen, b. the nature and form of the corrosion products, and c. alterations in the properties of the corrosive medium.—MA. 5269

## 3. CHARACTERISTIC CORROSION PHENOMENA

## 3.2 Forms

3.2.2, 3.7.2, 6.4.2

**Pitting Corrosion Characteristics of Aluminum: Influence of Magnesium and Manganese.** P. M. AZIZ AND HUGH P. GODARD. *Ind. and Eng. Chem.,* **44,** No. 8, 1791-1795 (1952), Aug.

This work was undertaken to determine the influence of alloying magnesium and manganese with aluminum upon its pitting probability and pitting rate. Aluminum in the purity range 99.5 to 99.99% was investigated using additions of 1.0% magnesium, 1.25% manganese, and 0.5% magnesium-0.5% manganese. The additions reduce the probability of pitting and also the rate. The magnesium-manganese addition reduces the pitting probability most but the straight manganese addition has the greatest effect in slowing the rate of pitting. Above 99.7% purity the probability of pitting is reduced with increasing purity. The beneficial effects of magnesium and manganese are valid in the range above 99.5% aluminum. Aluminum, to be used in environments where pitting corrosion may be encountered, should be allowed with magnesium and/or manganese. Commercial alloys of this type are 52S (2.5% magnesium) and 3S (1.25% manganese). —NSA. 5353

3.2.2, 3.7.4, 6.2.3, 4.3.6

**Influence of Thermal Treatment on Rate of Cracking of Carbon Steel Caused by Ammonium Nitrate.** (In Polish). M. SMIALOWSKI, E. GASIOR, AND C. BIENIOSEK. *Prace Glownego Inst. Met.,* **3,** No. 1, 17-22 (1951).

Above was studied for samples of sheet steel containing 0.11% carbon and 0.034% aluminum under constant tension and


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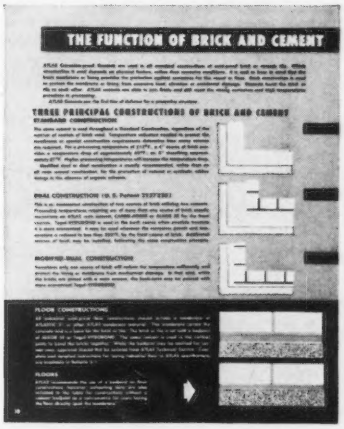

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immersed in a 40% aqueous solution of ammonium nitrate at 98°C. Analysis of the results indicates that the form and the distribution of the cementite phase in steel is related to the rate of cracking. $Fe_2Cu$ is cathodic with respect to iron and opposes the action of nitrate; but its presence causes the formation of local cells which accelerate the anodic dissolution of material at the grain boundaries. Apparatus is diagrammed; results are charted and illustrated by photomicrographs.—BLR. 4993

3.2.2, 5.9.4

**The Occurrence of Intercrystalline Attack in Materials to B.S. Specification L40 During Anodic Treatment.** B. W. Mott and M. B. Waldron. Protection and Electrodeposition of Metals. Selected Government Research Rep. Vol. 3, 1951, 149-153.

Experiments were made on various types of forged material to B.S. Specification L40, with surfaces in both sound and unsound conditions. Anodic treatment was carried out in both chromium tri-oxide and sulfuric acid baths to specification D.T.D. 910B, and dyeing was carried out with black dyestuffs with and without acetic acid addition. It was shown that anodizing in a chromium trioxide bath within the limits prescribed in D.T.D. 910B causes considerable attack on material already containing intercrystalline corrosion, the attack being apparently in the vicinity of the corrosion so that no fresh areas are attacked. When the destruction of unsound material is complete, the anodic coating is capable of a high degree of resistance to further attack on the metal. Treatment in sulfuric acid anodizing bath has very little tendency to open up existing attack and has no deleterious effect on sound material, but the film produced did not appear to be capable of preventing further attack as effectively as the chromium tri-oxide produced film. The use of acetic acid in the dye bath is liable to cause extended attack when used in conjunction with the sulfuric acid solution but not with the chromium tri-oxide solution. The most important conclusion of the work is that both the sulfuric acid and chromium tri-oxide baths may be used, within the specified limits of working conditions, for treating material conforming to B.S. Specification L40 of sound surface condition without risk of adverse action on the alloy.—MA. 4988

3.2.2, 8.9.4, 7.6.4

**Materials Testing to Establish the Cause of the Explosion of a Fireless Locomotive by Fracture of the Boiler Flange.** (In German). Hans Biegler. *Die Technik,* **7,** 131-134 (1952) Mar.

Intercrystalline corrosion is shown to have been the cause of the explosion. Photographs, photomicrographs, tables and references.—BTR. 5305

3.2.3

**Investigations on the Mechanism of Oxidation of Iron Single Crystals.** (In French). J. Bardolle and J. Benard. *Rev. Met.,* **49,** No. 9, 613-622 (1952).

A study of the formation of colored interference films on iron up to 300° C. in oxygen at atmospheric pressure, the nucleation of oxide films at very low oxygen pressures up to 850°C., the growth of oriented films (epitaxy) up to 850°C. at pressures of 0.1 to 0.01mm. mercury, and oxidation at low pressures below 850°C. (the thickness diminishes rapidly with decreasing temperature and interference colors appear). The research is continuing.—BNF. 5438

3.2.3, 3.4.6, 6.2.2

**Reaction of Iron with Ozone.** (In Russian). R. Kh Burshtein and N. A. Shumilova. *Doklady Akad. Nauk. S.S.S.R.,* **83,** No. 2, 251-252 (1952) Mar. 11.

Enrichment of oxygen with ozone had no marked effect on oxide film formation between —83 and 157°C.—BNF. 5346

3.2.3, 3.7.2, 6.2.2

**Influence of Silicon Content on Mechanical and High-Temperature Properties of Nodular Cast Iron.** W. H. White, L. P. Rice, and A. R. Eleaa. Am. Foundrymen's Soc., Preprint No. 51-5, Apr. 1951, 9 pp.

Two series of cast irons of similar compositions, one containing flake and the other containing spheroidal graphite, were used. Growth and scaling characteristics were also investigated. Photographs and micrographs illustrate results. Data are tabulated and charted.—BLR. 5432

3.2.3, 4.4.2, 6.5

**The Orientation and Disorientation of Fatty-Acid and Soap Films on Metal Surfaces.** James Woodham Menter. Abs. Dissert. Univ. Cambridge, 1949-1950. (1951), 200-201.

The structure and orientation of thin films of normal saturated fatty acids and metal soaps on metal surfaces were studied by electron diffraction. At room temperature molecules in films approximately 1 molecule thick, formed by rubbing or retraction, are arranged with their dipolar heads adsorbed on the metal surface, and the hydrocarbon chains approximately normal to the surface. On all metals the shorter-chain compounds are not so well oriented as the longer chains. The shorter chains are better oriented on chemically reactive metals than on non-reactive metals. On heating, a transition temperature may be observed at which the surface film becomes disoriented owing to thermal motion. This temperature is specific to the chemical nature of the metal surface and the nature of the film. On platinum, with fatty acids, the temperature is near the bulk melting point of the acid. On cadmium, zinc, mild steel, and nickel it is much higher. It is suggested that this much higher transition temperature is associated with the formation, in situ, of a metallic soap. The behavior of copper and silver is anomalous. The transition is reversible; the oriented layer may be evaporated off a platinum surface at high temperatures but is retained, after similar treatment, on a chemically reactive surface. Correlation of these transition temperatures with those observed in the frictional behavior of fatty acids and soaps is discussed. The role of the boundary lubricant is to form a thin film of molecules with their hydrocarbon chains oriented normally to the surface.—MA. 4990

3.2.3, 6.2.5, 3.5.9

**High Temperature Oxidation of Some Iron-Chromium Alloys.** D. Caplan and M. Cohen. Paper before AIME, Philadelphia, Oct., 1952. *J. Metals* (AIME), **4,** No. 10, 1057-1065 (1952) Oct.

Scaling characteristics of 3 stainless steels, Type 410 containing 11.44% chromium and 0.21% nickel, Type 430 containing 15.78% chromium and 0.43% nickel and Type 446 containing 26.54% chromium and 0.32% nickel were investigated by determining their weight gain vs. time curves at 1600°-2000°F. The scales formed thereby were examined using the techniques of X-ray diffraction and spectrographic and metallographic analyses in an attempt to explain the discontinuities in the curves and to elucidate the mechanism of scaling. Graphs, photomicrographs and 33 references.—INCO. 5349

3.2.4

**Gases in Metals.** P. Bardenheuer. *Metall,* **6,** 351-356 (1952) July.

Discusses solubility of gases in metals and temperature-dependence of gas dissolution, effect on metal of a change in solubility, behavior of hydrogen in pickling of steel, aggregation of molecular hydrogen in material under high pressure, indications of presence of hydrogen in materials, gas-absorption of solid metals under heat, effect of reaction gases, gas-absorption of liquid metals, hazards with gas-containing materials in the melt, and degassing metal melts. Curves show hydrogen-solubility in titanium from 0 to 1100°C, and in nickel, copper and iron from 0 to about 1750°C. N. P. Allen's work on hydrogen-oxygen equilibrium in copper at 1150, 1250 and 1350°C is quoted.—INCO. 5431

## 3.5 Physical and Mechanical Effects

3.5.2

**The Influence of Surface Films on the Friction of Solid Bodies.** (In German). F. P. Bowden. *Schweiz. Arch. angew Wiss. u. Tech.,* **18,** 116-127 (1952) April.

Reviews recent investigations on the above, with particular respect to friction between metals. Effects of the mechanical properties of the oxide layers, of the lubricant film, and of attack by chemical agents are indicated. Tables and diagrams. 17 references.—BTR. 5428

3.5.3, 3.5.8

**The Engineering Aspects of Intimate Metallic Surfaces.** H. E. Arblaster. *Australasian Engr.,* **1952,** 43-58, Mar. 7.

Discusses following topics: cavitation erosion, covering mechanism, effect of some variables, testing cavitation resistance; metallic wear covering galling, scuffing, etc.; problems of metallic surfaces nominally at rest; problems of surfaces in motion; friction and frictional resistance of metals; lubrication by thin metallic films; surface films; boundry lubrication; extreme pressure lubricants; and fretting corrosion and variables affecting it. Tables and photographs. 34 references.—BTR. 5427

3.5.3, 5.1

**War on Wear.** H. Blok. Paper, International Symposium on Abrasion and Wear, Delft, Nov. 14-15, 1951. *Engineering,* **173;** 594, 625-626 (1952) May 9, May 16.

Wear, defined as the undesirable migration from a solid surface, is divided into two classes, single-sided wear by flowing fluids including fluidized solids, and double-side wear with solid-solid contact. Methods of combating wear are protective layers such as coatings, lu-

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brication, oxidation and other surface treatments, conversion or exchanging an undesirable type of wear for a permissible one, and diversion or diverting wear from one surface to a less valuable or more easily replaceable one. Qualitative analysis of wear is well developed but not the quantitative. 5304

**3.5.3, 5.9.3**

**The Effect of Shot-Peening on Damage Caused (to Steel and Brass) by Cavitation.** NICHOLAS GROSSMAN. A.S.T.M. Bull., No. 183, 61-66 (1952).

When the relative motion between a metal and a liquid is sufficiently high, the collapse of vapor cavities may cause erosion and pitting of the metal surface. This can be avoided by proper design, but occasionally higher efficiency or better economy is attained by operating near cavitation conditions or even with occasional cavitation present. It is then necessary to use materials less susceptible to cavitation damage. The effect of shot-peening on the rate of cavitation damage in a vibratory apparatus, using the magnetostriction principle, was investigated. Two steels and a brass containing copper 66.5% and zinc 33.4% were tested, the brass specimens being obtained from ½-inch thick, cold-rolled, ½-hard plate. The damage, as measured by rate of weight loss/unit time, was decreased by shot-peening, the amount of decrease varying from 7% for one of the steels to 58% for the brass. 8 references.—MA. 5463

**3.5.3, 6.2.2**

**Castings to Resist Abrasive Wear.** E. J. BROWN. *Foundry Trade J.*, **92**, No. 1866, 587-595 (1952) June 5.

In all cases, abrasion-resistance is a comparative quality, but there are types of service requirements for which it is possible to postulate suitable qualities of resistant materials from experience of a number of applications. Corrosion and hardness are 2 of the factors considered. The way in which manganese-steel as well as alloy cast irons (nickel containing) and other alloy steels (nickel-chromium-molybdenum) were developed to meet service conditions is shown. The manufacturing methods and applications for these materials are given. Nickel hard type cast iron has replaced chilled cast iron in many applications. Flame hardening, nitriding, and surface deposits of abrasion-resisting material are considered. Graphs, photomicrographs and illustrations are included.—INCO. 5423

## 3.6 Electrochemical Effects

**3.6.8, 3.8.2, 3.8.4**

**Hydrogen Overvoltage, Electric Double Layer, and Related Questions.** GENEVIEVE SUTRA. *J. Phys. Radium*, **12**, No. 6, 673-681 (1951).

Recent theories of the nature and origin of hydrogen overvoltage, more especially that due to Darmois [ibid., **11**, 577 (1950)] are briefly reviewed. Sutra has recently shown that the $H^+$-ion is simply a proton; previous theories had conceived it as composed of a free proton encased in a molecule of water,

**3.6.2, 3.4.9, 2.3.4**

**Experimental Approach to the Problem of Tuberculation by Waters.** R. S. THORNHILL. *Chemistry & Industry*, **1951**, 1201-1205; Disc. 1205-1207, Dec. 21.

The effect of water composition on corrosion under flow conditions was investigated by passing synthetic waters around the outside of bright steel tubes parallel to the long axis. The corrosion pattern of simple salt solutions consisted of parallel lines of bright and rusting metal which represented cathodic and anodic areas respectively. Solutions of salt mixture such as 20 p.p.m. of sodium bicarbonate and 16 p.p.m. of calcium sulfate caused rust blisters which are believed to be the beginning of tuberculation. The effects of varying pH and adding materials to the water was studied, and the results applied to treatment of a natural low-hardness water containing 16 p.p.m. of chloride. Best results were obtained with "Calgon" sodium hexametaphosphate and "Micromet" sodium calcium hexametaphosphate. 5449

**3.6.8, 3.8.2**

**Influence of Certain Surface-Active Compounds on the Hydrogen Overvoltage of Platinum and Copper.** R. D. MISCH AND R. B. BERNSTEIN. *J. Phys. & Colloid Chem.*, **55**, 1401-1409 (1951) Nov.

Further information on the hydrogen-discharge process where various foreign species are present at low concentration in the electrolyte. The linearity of the hydrogen overvoltage vs. log current density relationships were verified for platinum and copper. A rapid recording apparatus is described.—MR. 4973

**3.6.8, 3.8.4**

**Theory of Overvoltage and Mechanism of Corrosion.** R. AUDUBERT. *J. Chim. Phys.*, **49**, No. 7-8, C97-103 (1952) Aug.-Sept.

The theory of overvoltage is applied to corrosion phenomena, and the fundamental theoretical relations of these processes are obtained. Corrosion by direct attack, by secondary reaction in the absence of atmospheric oxygen, and in the presence of oxygen, are treated kinetically. 5319

**3.6.6, 6.3.6, 3.7.2, 4.3.1, 4.4.1**

**The Corrosion-Resistance of Copper and Some Copper Alloys.** C. VAN DUIJN, JR. *Polytechn. Tijdschr.*, **6**, Nos. 7/8, 119a-127a (1951).

A general account is given of the corrosion-resistance of copper (99.9% purity) and its alloys with zinc, tin, aluminum, and silicon. Galvanic corrosion and stress-corrosion phenomena are dealt with. The action on copper and its alloys of the following solutions is described. Hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid, sulfur dioxide, acetic acid, fatty acids, and alkaline, ammonia, and saline solutions. A table sets out the relative corrosion-resistance of copper, bronze (copper 88, tin 10, zinc 2%), silicon bronze (copper 97, silicon 3%), aluminum bronze (copper 95, aluminum 5%), red brass (copper 85, zinc 15%) and yellow brass (copper 60-70, zinc 40-30%) in some 160 solutions.—MA. 5170

**3.6.6, 5.3.2, 6.4.2, 6.2.3**

**The Protection of Steel Bolts Used in Aluminum Structures.** Tin and Its Uses. No. 25, 3 (1951) Dec.

Steel bolts with various protective treatments were fixed into aluminum plates and exposed for 26 weeks to 3% sodium chloride spray; humid, sulfur-dioxide containing atmosphere; and to natural marine and industrial environments. The protective coatings used were: sherardized, zinc plated, black oxide finish, cadmium plated, parkerized, and tin-zinc alloy coated. Best protection was obtained from the 80/20 tin-zinc alloy coating which permitted easy removal of the bolts from the aluminum plates after the test and produced a minimum amount of plate corrosion. Zinc coatings gave the next best all-around performance. Although the zinc was appreciably corroded at the end of the test period, the aluminum plates were only slightly attacked and the steel base was fully intact. The bolts were not as easy to unscrew as those protected with the tin-zinc alloy. None of the other protective coatings were entirely satisfactory. In some cases, severe corrosion of the aluminum occurred and the bolts were difficult to remove. The sodium chloride spray was a more severe test than the sulfur dioxide loaded atmosphere. Field tests confirmed the relative merits of the finishes as determined in the laboratory tests. Unprotected steel and brass bolts were included for comparison.—PDA. 5137

**3.6.8, 2.4.4, 2.3.5**

**Electronic Instrumentation for Overvoltage Measurements.** DIMITRIOS STAICOPOULOS, ERNEST YEAGER, AND FRANK HOVORKA. *J. Electrochem. Soc.*, **98**, No. 2, 68-73 (1951).

Electronic instrumentation has been developed for the measurement of overvoltage by the commutator or indirect method. The current may be interrupted for periods ranging in length from 5 microseconds to one-half the repetition rate for repetition rates from 20 to 3000 $sec.^{-1}$. Polarizing currents are continuously variable from $10^{-6}$ to $10^{-1}$ amperes. Provision is made for measuring rapidly varying potentials during periods as short as 5 microseconds at any known time after the interruption or initiation of the polarizing current, thus permitting quantitative study of the decay as well as the build-up of anodic or cathodic polarization. The potential measurements involve the use of a gated-bridge null detector in conjunction with an ordinary potentiometer. Typical accuracy of the potential measurements is ± 5 milli-volts for measurement periods of 5 microseconds duration at a repetition rate of 1000 $sec.^{-1}$. 4 references.—MA 5071

## 3.7 Metallurgical Effects

**3.7.1, 3.5.9, 6.2.3, 2.3.7, 3.5.1**

**Microstructural Instability of Steels for Elevated Temperature Service.** G. V. SMITH. W. B. SEENS, H. S. LINK, AND P. R. MALENOCK. *Am. Soc. Testing Materials*, Preprint No. 28, 1951, 18 pp.

Describes effect of exposure for 10,000 hours (about 14 months) at 900, 1050, or 1200°F. on microstructure, hardness at room temperature, and notch-impact strength at different temperatures of 18 ferritic or austenitic steels which may be applied at elevated temperatures.—BLR. 5000

**3.7.1, 6.2.2**

**The Structure of Corrosion-Resistant Silicon Cast Iron.** A. WITTMOSEE AND E. PIWOWARSKY. Neue Giesserei, Tech. Wiss. Beih, No. 2, 83-86 (1950) Feb. *J. Iron Steel Inst.* (London), **169**, Part 1, 89 (1951) Sept.

The composition of corrosion-resistant

13-16% silicon iron corresponds to the α-solid solution of the iron-carbon-silicon system, yet many physical properties indicate that it cannot be a homogeneous solution. It has not been possible to examine the alloy metallographically because the corrosion resistance has made etching impossible. It has been found that alkaline sodium picrate, 80% phosphoric acid or hydrofluoric acid-nitric acid-water mixtures will reveal the micro-and micro-structures of the alloy, especially if used hot. A marked segregation is found in the grains of the solid solution and it appears to be due to decomposition of a silicon-rich silicon carbide.—INCO. 5251

**3.7.2, 4.3.2, 6.2.5**

**Influence of Composition of Corrosion-Resisting Steels On Resistance to Sulphuric and Hydrochloric Acids.** K. BUNGARDT AND H. J. ROCHA. Paper before Dechema Mtg., 1951. *Werkstoffe u. Korrosion,* **3,** 209-211 (1952) May-June.

Consideration of materials in which chromium is passivating agent, and materials which, in spite of their chromium content, assume the characteristics of nickel alloys. Experiments on steels and alloys with varying contents of nickel, chromium, molybdenum, copper and iron, with notes on the influence of the individual nickel, chromium, molybdenum and copper contents are described.—INCO. 5378

**3.7.2, 6.2.1, 2.3.6, 7.7**

**Structures of Iron-Nickel-Aluminum Alloys for Permanent Magnets.** I. SKAKOV. *Doklady Akad. Nauk SSSR,* **79,** 77-80 (1951) July 1.

Metallographic analysis of iron-aluminum-nickel alloy with optical and electron microscopes provides data for adding to and correcting Bradley and Taylor's diagram for this system. Results are discussed and illustrated.—INCO. 5254

**3.7.2, 6.2.5, 2.3.4**

**Improving Stainless Quality by the Use of Minor Selenium Additions.** R. J. WILCOX. Michigan Steel Casting Co. Alloy Casting Bull., No. 15, 1-2, 5-6 (1951) Mar.

A late addition of selenium to the melt, either in the ladle when tapping from larger furnaces, or in the molten bath in induction furnaces, will effectively prevent the last traces of internal gas voids in 18-8 type stainless steel. Addition of as low as 0.01% selenium was an effective degasification agent and can be relied on from heat to heat. Selenium is added in the form of 50-50 ferro-selenium. Additions of selenium up to 0.085% did not have any effect on the mechanical or physical properties of stainless steels CF-8 (9.1% nickel, 19.33% chromium, 1.01% silicon, 0.07% carbon), CF-8M (11.79% nickel, 18.82% chromium, 1.12% silicon, 2.8% molybdenum), and FA-20 (30.2% nickel, 19.79% chromium, 1.02% silicon, 4.43% copper, 3.60% molybdenum). Corrosion studies were made by the boiling 65% nitric acid test. Selenium and tellurium can be used interchangeably with equal effectiveness.—INCO. 5271

**3.7.3, 3.5.8, 3.5.7**

**Effect of Internal Pressure on Stresses and Strains in Bolted-Flanged Connections.** D. B. WESSTROM AND S. E. BERGH. Du Pont. Paper, A.S.M.E. Ann. Meet., N. Y., Nov. 26-Dec. 1, 1950. *Trans. Am.*


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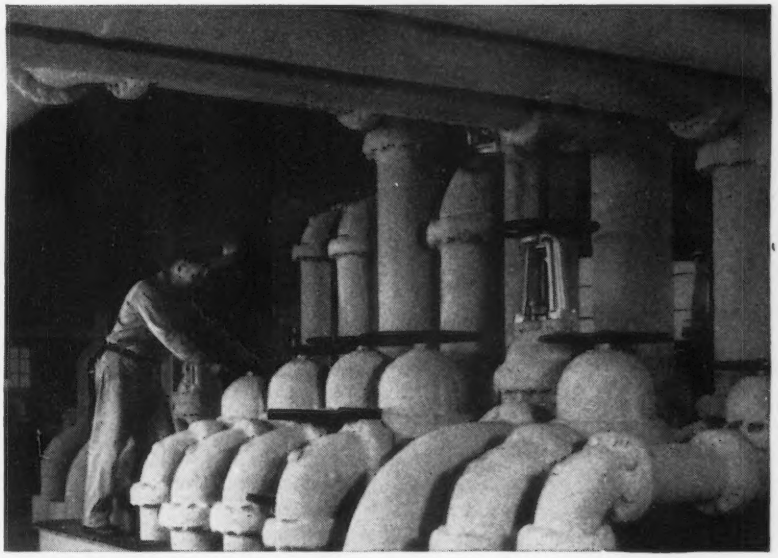

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*Soc. Mech. Engrs.*, **73**, 553-562, disc. 562-568 (1951) July.

It is shown that the elastic deformation, and therefore the forces and moments, in a bolted-flanged connection vary with the magnitude of the internal fluid pressure, and that the actual conditions existing in a bolted joint will be considerably different from those assumed in the concept of design on which the rules of the A.S.M.E. Unfired Pressure Vessel Code are based. For certain critical ranges of joint diameter, pressure and stress, it is important to analyze the design for the actual conditions that will be obtained a. in assembling the joint, b. at test pressure and c. in service. Formulas are derived for calculating these conditions and the results are summarized in the form of a design procedure. 5276

**3.7.3, 3.7.4, 3.5.9, 6.2.5**

**Effect of Prior Treatment on Precipitation of Sigma Phase.** G. V. Smith, E. J. Dulis, and H. S. Link, *Welding J.* (N. Y.), **30**, 385s-396s (1951) Aug.

Effect of heating between 1700 and 2300°F. after cold deformation, and of cooling rate therefrom, on the formation of the sigma phase in 18% chromium-8% nickel-niobium and 25% chromium-20% nickel stainless steels during subsequent exposure at 1300°F. for up to 7500 hours is discussed and illustrated. Numerous micrographs, charts, and tables.—BLR. 5415

**3.7.3, 6.2.5, 8.6.3**

**Corrosion Resistance of Weld Zone in Stainless Steels.** (In Japanese). Tetsutaro Mitsuhashi, Yutaka Imai, Manabu Ueno, and Toshiaki Hagiwara. *J. Mechanical Laboratory* (Japan), **5**, 262-268 (1951) Oct.

Presents comprehensive description of the above as encountered in the Japanese textile industry. Data are tabulated and charted for various chemical solutions and stainless-steel compositions. Results are summarized in English.—BTR. 4950

## 3.8 Miscellaneous Principles

**3.8.2, 5.2.3, 3.2.2**

**Effect of Anions on the Electrolytic Behavior of Metals.** A. Vyskocil. Collection Czechoslov. Chem. Communs. (Czechoslovakia), **15**, 1101-1106 (1951).

Previous expositions by Vyskocil on the corrosion of magnesium and iron are explained by the formation of local elements with adsorbed anions as local anodes. Strongly adsorbed anions form a protective film, so the corrosive power is inversely proportional to the adsorptivity of the anion. Since the anions are not consumed in the process, they may be considered to be catalysts. Carbon dioxide, carbonates, and salts of weak acids are as corrosive as salts of strong acids.—ALL. 5261

**3.8.2, 6.2.2, 5.8.2**

**Irreversible Electrode Potentials of Iron in Electrolytes Containing Corrosion Inhibitors.** (In Russian). I. L. Rozenfel'd. *Bull. acad. sci. U.R.S.S.* (Izvest. Acad. Nauk, SSSR). Section of Chemical Sciences, **1951**, 674-677, Nov., Dec.

A study was made of the above in electrolytes containing sodium nitrite and zinc sulfate as inhibitors. Data are charted.—BTR. 5268

**3.8.2, 6.3.15, 4.3.2**

**The Difference Effect on Titanium Dissolving in Hydrofluoric Acid.** M. E. Straumanis and P. C. Chen. *J. Electrochem. Soc.*, **98**, No. 9, 351-355 (1951).

Commercial titanium was coupled with platinum and the difference effect measured during its dissolution in 0.1, 0.24, 0.5, 1.0, and 2 normal hydrofluoric acid. The difference effect was almost independent of the acid concentration and was directly proportional to the galvanic current up to current density of 40 or 60 milliamperes per sq. centimeter. The theory of local elements adequately explained all the properties of the difference effect, indicating that the dissolution of titanium in hydrofluoric acid is an electrochemical process. The degree of polarization of local elements formed on different metals can be determined by the difference effect. 13 references.—MA. 5255

**3.8.2, 6.6.4**

**Graphite as an Anode.** (In German). Heinrich Thiele and Eberhard Weise. *Z. Electrochem.*, **55**, 193-199 (1951) Apr.

Effects of nature and concentration of mineral-acid electrolytes on anodic oxidation were investigated. Results show that evolution of oxygen is accompanied by corrosion of the honeycomb planes of the graphite lattice and of the $C_6$ rings. Photographs, diagrams, and graphs. 20 references.—BLR. 5259

**3.8.3, 6.3.8, 3.8.2**

**Study on the Anodic Passivation of Lead, Part I. Effect of $Cl^-$ and $Co^{++}$ Ions on the Passivation of Lead in Zinc Sulfate Solution.** (In Polish). M. Smialowski and E. Przybyla. *Prace Glownego Inst. Met.*, **3**, No. 6, 501-505 (1951).

The change of lead anode potential with time was studied experimentally at various current densities, using a Curie electrometer and a photographic recorder. Typical potential-time curves obtained under "normal" experimental conditions are presented. Results obtained with pure lead anodes and with lead anodes containing 1% silver are compared.—BTR. 4997

**3.8.4**

**The Work Functions of Copper, Silver, and Aluminum.** E. W. J. Mitchell and J. W. Mitchell. Proc. Roy. Soc., ser. A, **210**, 70-84 (1951) Dec. 7.

Presents results of a study of changes in the work functions of metallic surfaces which result from adsorption of oxygen and formation of oxide films upon them. Copper, silver, and aluminum were used for these experiments, because they show three distinct types of behavior when they react with oxygen. 22 references.—BLR. 5364

**3.8.4**

**Adsorption of Oxygen on Silver.** F. H. Buttner, E. R. Funk, and H. Udin. *J. Phys. Chem.*, **56**, 657-660 (1952) May.

Results of determinations of the surface tension of solid silver in pure helium and in an atmosphere of controlled helium-oxygen mixtures. Apparatus diagrams, graphs, and 10 references.—MR. 5421

**3.8.4, 2.3.9**

**The Mechanism of Exchange Between Radioactive Ions in Solution and Metal Surfaces.** M. T. Simnad, and R. C. Ruder. Paper before Electrochem. Soc., Buffalo, Oct. 11-13, 1950. *J. Electrochem. Soc.*, **98**, No. 8, 301-306 (1951) Aug.

The mechanism of exchange between metals and ions in solution was studied with radioactive cobalt in solutions into which etched and ground specimens of cobalt, nickel, iron, 18-8 stainless steel, titanium, platinum, copper, copper-platinum-brass were immersed in the presence and absence of oxygen. The radioactivity of the metals and the distribution of cobalt on the surfaces was determined. The results indicate that local cell action, due to differences in potential on the metal surfaces, is the factor which governs the radioactivity acquired by the metals. The influence of oxygen depends on the protective nature of the oxide film formed. The orientation of the grains markedly affects the distribution and amount of activity that is acquired.—INCO. 5006

**3.8.4, 2.3.9, 6.2.1**

**Study of the Selective Oxidation of the Ferro-Nickel Alloys by X-Ray Diffraction.** Jean Moreau and Jacques Benard. *Compt. rend.*, **232**, No. 20, 1842-1843 (1951).

L. B. Pfeil [*J. Iron Steel Inst.* (London), **119**, 50 (1929)] and others have shown that when an iron-nickel alloy is exposed to air at high temperature selective oxidation occurs, the proportion of iron in the oxide increasing with the time. Moreau and Benard recently [*Rev. Met.*, **47**, 317 (1950)] showed that by chemical analysis of the underlying metal the evolution of this reaction could be followed. Since thicknesses of the metal of the order of 0.01 mm. are involved, a more delicate method is required, and Moreau and Benard applied X-ray back-reflection analysis to measure the crystal parameter of the $FeNi_3$-$\nu$ solid solution with an accuracy of $\pm 0.0003$ Å. They also studied by this method the metallic phase in immediate contact with the oxide in the alloys containing 5, 10, 20, and 30% nickel. The enrichment of nickel is very rapid at first and then slows down progressively, tending in all cases towards pure nickel according to the reaction: Ferric oxide (rich in iron) + nickel oxide → ferric oxide (poor in iron) + nickel. Nickel oxide appears to be unable to co-exist with ferric oxide in the presence of iron.—MA. 4963

**3.8.4, 3.7.4, 6.2.3**

**Influence of Temperature on Corrosion Rates in Moving Conditions.** F. Wormwell and H. C. K. Ison. Gt. Brit. Dept. of Sci. and Ind. Res., Chem. Res. Lab., Teddington. *Chemistry & Industry* (London), No. 15, 293 (1951) April 14.

The influence of temperature on the corrosion rate of mild steel at high speeds of movement of aqueous solutions is greater than would be expected from previous work under static conditions. Under conditions of rapid movement, the rate-controlling processes are of a chemical rather than of a physical nature. Under stagnant conditions, however, the rates of diffusion and convection of dissolved oxygen influence the corrosion rates.

The corrosion rate of grit-blasted mild steel specimens was almost doubled by a rise in temperature from 25° to 30°C, whereas the corrosion rate of emeried specimens usually increased only 50%. Different corrosion rates for the two surfaces can be expected because of the differences in residual stresses, distortion, and flow of the metal, and because of the different character and thickness of the oxide films formed during the sur-

face preparation. These factors make the grit-blasted steel more reactive than the emeried surface.

Specimens of mild steel 1 meter sq. were prepared either by emerying on Oakey's IF paper followed by degreasing in liquid benzene, or by grit-blasting with steel grit and degreasing in benzene vapor. The samples were immersed in 0.1 normal sodium chloride solution for 2 days at temperatures of 22°-30°C. while being revolved at a speed of 1,965 feet per minute.—PDA. 5275

3.8.4, 3.8.2, 3.6.8

**The Mechanism of the Cathodic Hydrogen Evolution Reaction (on Mercury, Silver, Nickel, and Platinum).** J. O'M. Bockris and E. C. Potter. *J. Electrochem. Soc.*, **99**, No. 4, 169-186 (1952).

Some of the problems of concept and mechanism in the field of cathodic hydrogen evolution are discussed and clarified. It is shown that a full derivation and correlation of kinetic equations which assume no mechanism reveals expressions for several parameters which take values specific to one or more mechanisms. In the estimation of the value of these parameters, the statistical method of treating data has proved indispensable, but a further method of ascertaining the mechanism of the reaction is to examine the kinetics of the individual reaction paths so that the expected values of the parameters common to all paths may be deduced. Treatment of a number of mechanisms important in acid and alkaline solutions shows them to be distinguishable experimentally. Using published data, the actual conditions under which various reaction paths take place at mercury, silver, nickel, and smooth platinum cathodes are calculated. These deduced paths can be compared with observation, thus verifying the occurrence of a particular reaction path. It is also possible to demonstrate the impossibility of some mechanisms in specific cases. Recent advances which the methods described have made possible are discussed in relation to data which have now become available. 27 references.—MA. 5395

3.8.4, 4.3.2, 6.2.2, 6.3.3

**The Problem of the Mechanism Determining the Rate of Solution of Metals in Concentrated Acids.** (In Russian). Ia. V. Durdin. *J. Gen. Chem.* (U.S.S.R.) (Zhurnal Obshchei Khimii), **22**, No. 84, 3-17 (1952) Jan.

A study was made of the solution of iron and chromium in hydrochloric acid and sulfuric acid. Data are tabulated and charted. 14 references.—BTR. 5476

3.8.4, 4.4.7, 6.5

**Catalytic Effect of Metals on Oxidation of Lubricating Oils.** D. W. Sawyer. Paper, A.S.M.E. Meet. Petr. Div. Toronto, June 1951; *Sci. Lubrication*, **3**, No. 8, 16-17 (1951) Aug.

Aluminum and stainless steel were found to have little or no catalytic effect on the oxidation of lubricating oils and to resist corrosion by oxidized oils better than other commercial metals. Copper and low-carbon steel accelerated oxidation markedly. Copper, lead, and zinc, in general, were corroded to a much greater extent than were any of the other metals. In a number of cases low-carbon steel, pure magnesium, magnesium AM3S, and tinplate were also less resistant to corrosion. 4967

3.8.4, 6.2.2, 3.7.4

**Role of Crystal Orientation in the Oxidation of Iron.** Earl A. Culbransen and Roswell Ruka. *J. Electrochem. Soc.*, **99**, 360-368 (1952) Sept.

Describes and illustrates results of experiments made using the electron-diffraction high-temperature camera for the oxidation of single crystal of iron as related to the processes of oxidation and corrosion. Photographs and tables. 32 references.—BTR. 5414

3.8.4, 6.2.2, 4.3.2

**Solution of Iron by Dilute Sulfuric Acid in a Magnetic Field.** F. Blaha. *Monatsh.*, **83**, 248-250 (1952) Feb. 15.

Tabulated data confirm Ehrenhaft's discovery that a magnetic field increases the evolution of oxygen due to solution of iron in dilute sulfuric acid.—BTR. 5326

3.8.4, 3.2.3, 6.4.2

**Structure of Amorphous Aluminium Oxide Films.** H. G. F. Wilsdorf, *Nature*, **168**, No. 4275, 600-601 (1951) Oct. 6.

Electron diffraction photographs of the oxide coating on aluminum reveal two diffuse rings which can be interpreted as a size effect only, the assumption being that the material consists of normal crystals the grain size of which is exceedingly fine. The second possibility is that the layer consists of totally disordered, uniformly built molecular groups. The diffraction patterns show that amorphous aluminum oxide consists of tetrahedral particles. In an attempt to find the atomic arrangements of the groups, aluminum oxide appeared to give the best results. A further paper will be published on the mechanism of oxidation.—ALL. 5224

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## 4. CORROSIVE ENVIRONMENTS

### 4.2 Atmospheric

4.2.3, 4.6.2, 7.4.2

**Behavior of Superheater Tubing Materials in Contact with Combustion Atmospheres at 1350°F.** H. A. BLANK, A. M. HALL AND J. H. JACKSON. Battelle Memorial Institute. Paper before ASME, Ann. Mtg., Atlantic City, Nov. 25-30, 1951. *Trans. Am. Soc. Mech. Engrs.*, **74,** No. 5, 813-819 (1952) July.

Evaluation of commercially available alloys for suitability as superheater and reheater tubing at metal temperatures up to 1350°F. One part of the program deals with the reaction of high-pressure, high-temperature steam on such materials. The other part is concerned with corrosion by flue gases and slag-forming ash on the external surface of the tubing. The test materials consisted of austenitic stainless steels, nickel-base alloys, such as Inconel and Illium G, and aluminized mild steel. In the tests reported, low-sulfur coal and gas produce combustion products which are only mildly corrosive. High-sulfur, high-alkali, and high-vanadium fuels produce combustion products which are often extremely corrosive toward metals. Photomicrographs, tables, graphs and 11 references are given.—INCO. 5437

### 4.3 Chemicals, Inorganic

4.3.2

**Corrosion: Metals for Use with Nitric Acid.** M. G. FONTANA. *Ind. and Eng. Chem.*, **44,** No. 10, 101A-102A, 104A (1952) Oct.

Three classes of metals are available for service in handling straight nitric acid. High silicon irons, 18-8S (type 304) and 17% chromium (type 430) stainless steel are generally used for a variety of conditions of temperature and concentration. Titanium, aluminum, Type 316 (18-8S-Molybdenum) and Duriclor are used under certain conditions only because of cost, limited corrosion resistance, resistance only to specific concentrations or a combination of these. Inconel, Illium, and Durco D-10 do not offer increased corrosion resistance to justify their cost. Ordinary cast iron, nickel cast irons, magnesium, steel, and low alloy steels are generally not used because of insufficient corrosion resistance.—INCO. 5482

4.3.2, 6.2.2

**Action of Dilute Sulfuric Acid on Magnetized Iron.** G. WAGNER AND F. BLAHA. *Nature,* **168,** 74 (1951) July 14.

It has been stated that in addition to hydrogen, oxygen is evolved in considerable quantities in above reaction whereas with unmagnetized iron no such phenomenon occurs. Results obtained using spectroscopically pure iron show that this difference is apparently nonexistent. —MR. 5264

4.3.2, 6.2.2, 6.2.3

**Construction Materials That Stop Sulfuric Acid Corrosion.** Parts 1 & 2. S. W. SHEPARD. *Industry and Power,* **61,** 99-100, 85+ (1951) Nov., Dec.

Types and applications of materials that help in solution of problems involving corrosion, abrasion, heat, and pressure. Limitations in the use of cast iron and steel and ways of compensating for them.—MR. 4996

4.3.2, 6.2.5

**The Corrosion of 18-8 Stainless Steel in Acid Copper Sulphate.** J. BLETON, J. BLANOT, AND P. BASTIAN. *Sheet Metal Ind.*, **29,** 369-370 (1952) Apr.

In view of variance in corrosion resistance of 2 metals of nearly identical composition, an investigation was made to determine correction. 91 melts were studied. Results are presented.—BTR. 5328

4.3.2, 6.4.2

**Aluminum Alloys for Handling and Storage of Fuming Nitric Acid.** W. W. BINGER. *Corrosion* (News Section), **8,** 1 (1952) Jan.

Results of tests showing the resistance of aluminum to corrosion by nitric acid. —MR. 5278

4.3.3, 3.5.8

**Corrosion: Materials for Use with Caustic Soda.** M. G. FONTANA. *Ind. and Eng. Chem.*, **44,** No. 6, 81A-82A, 84A (1952) June.

Materials of construction for handling caustic soda are discussed with particular reference to stress-corrosion of welded steel. Nickel is the best material for handling caustic at all concentrations and temperatures including fused material up to 900°F. The only limitation is that severely stressed nickel may show cracking in strong caustic at temperatures of 600°F and higher. The rate of corrosion of steel by caustic at very high (550-600°F) temperatures is quite high and nickel or nickel alloy materials are required. Cracking because of the so-called caustic embrittlement is one of the early recognized forms of stress-corrosion. Graphs.—INCO. 5481

4.3.3, 6.3.10, 6.2.1, 5.4.5

**How to Handle Liquid Caustic.** R. A. SPRINGER. Paper before TAPPI, Ann. Mtg., 1951. *Chem. Eng.*, **58,** No. 8, 112-113, 282 (1951) Aug.

In a liquid caustic soda system, flange quality steel is preferred for tanks. Black iron, carbon steel, and cast iron are best for pipes and fittings. Cast iron pumps have a shorter life than nickel and nickel alloys. A small amount of iron contamination occurs with all-iron construction. If this is objectionable, nickel, nickel-clad steel or organic coatings may be used.—INCO. 5046

4.3.3, 6.3.21

**The Oxidation of Lithium and the Alkaline Earth Metals in Liquid Ammonia.** JOSEPH K. THOMPSON AND JACOB KLEINBERG. *J. Am. Chem. Soc.*, **73,** No. 3, 1243-1245 (1951) Mar.

A study of the oxidation behavior of lithium and the alkaline-earth metals in liquid ammonia, under conditions inhibiting amide formation in the case of sodium is reported. All the metals behave nearly alike under the conditions described, the product in every case containing chiefly monoxide and a relatively low proportion of peroxide. Dissolution data for the metals and absorption-spectra studies of the oxidized solutions are discussed.—MA. 5258

4.3.4, 5.9.1

**Corrosion by Retained Treatment Chemicals on Phosphated Steel Surfaces.** R. J. BROWN, S. S. CLARKE, AND E. E. LONGHURST. *J. Iron Steel Inst.*, **171,** Pt. 1, 58 (1952).

Brown points out that corrosion is not confined to creviced joints and illustrates effects obtained at the fringes of draining trails after chromic rinsing. The authors comment on his findings and point out the importance of effective rinsing to remove harmful materials.—RPI. 5425

4.3.5, 6.1

**Chlorine Bleaching.** E. R. BARKER JR. Hollingsworth and Whitney. *Paper Trade J.*, **135,** No. 20, 253-254, 256-257 (1952) Nov. 14.

In handling dry chlorine, drums and tank cars are made of steel. Valves are of bronze, or steel with Monel stems. Hastelloy C is used for valve trim. Steel pipe is used in all dry phases of the liquid and gas handling. When handling wet chlorine, Hastelloy C is used and high silicon cast irons have also been adopted. Several plastic materials have been developed that show great promise. Stainless steels are useful for low concentrations of chlorine but are apt to be rapidly attacked under some conditions.—INCO. 5357

4.3.5, 6.3.10, 3.5.9, 3.5.7

**Materials for Fluorine Control Equipment.** G. E. ZIMA AND R. N. DOESCHER. Calif. Inst. Tech. *Metal Progress,* **59,** No. 5, 660-663 (1951) May.

Handling liquid and gaseous fluorine under high pressure. Nickel and several high nickel alloys have good resistance to gaseous and liquid fluorine and have made possible the safe handling of it over a wide range of operating pressures and temperatures. A small capacity, high pressure storage tank for liquid fluorine is composed of an inner tank for liquid fluorine made of "A" nickel, a container for liquid nitrogen and a high vacuum insulating shell both of Monel. Nickel fluoride deposits resulted when water was not removed from the tank. Pure nickel is inferior to Monel as a liquid fluorine container because of its susceptibility to attack by hydrofluoric acid. Liquid nitrogen and vacuum jackets are used in liquid fluorine feed lines. The fluorine channel is made of "A" nickel seamless tubing. To reduce differential thermal expansion, the expansion ring and jacket tubes are made of Monel. Flange sections were of "K" Monel. Rings of soft nickel effected the interflange sealing. Age hardening did not prove to be detrimental to the fluorine resistance of "K" and "Z" Monel. A high pressure control valve for liquid fluorine has achieved complete shut-off for working pressures up to 800 psi by seating 25% aluminum against Monel. A Sylphon bellows of Monel was used to separate the secondary packing gland from the liquid fluorine.. The single-ply bellows was silver soldered to the pintle and body. The soldered areas were heavily nickel plated to provide corrosion resistance. A compact of flake graphite, powdered nickel and acid-treated shredded asbestos was used as a primary valve-stem packing for the liquid fluorine valve. "S" Monel was used in the piston housing. A 440-C stainless ball gave excellent service in a rolling ball type flowmeter. "Z" nickel, age hardened to Brinell 330, was employed for the critical orifice plate, track and retainer elements. The upstream and downstream

adapter sections and the casing were made of Monel. In the production of fluorine, Monel finds application as tubing, filter screens and thermocouple shields; nickel for the sodium fluoride purification towers. A simple globe-type valve with a cast nickel body, Monel pintle and soft nickel seating surface is used for control. Illustrations are given. —INCO. 5199

4.3.6, 3.6.10, 6.2.2, 6.6.5

**Corrosion of Iron in Concrete Caused by Alternating Currents.** OSCAR SOARPA. *Atti. accad. nazl. Lincei Rend, Classe sci. fis., mat. e nat.*, **10,** 275-280 (1951) April.

Alternating currents of industrial frequency flowing through reinforced concrete structures will not significantly corrode ferrous reinforcements provided chlorides are absent. Considerable corrosion damage can result, however, when steel is embedded in chloride-containing concretes, even if the chloride concentration does not exceed the amount commonly admixed as anti-freezing agent.

Pairs of mild steel cylinders, 1 cm diameter and 25 cm long, and pairs of iron bars, 20 by 2 by 0.2 cm, were inserted as electrodes 20 and 16 cm deep, respectively, in freshly cast chloride-free concrete and in concrete containing 50 grams per liter of sodium chloride. Alternating current of 160 volt potential and 42-cycle frequency, giving a current density of 0.2 amp. per sq. decimeter, was applied to the electrodes for 90 days.

After the test, electrodes immersed in chloride-free concrete were intact, whereas those embedded in the chloride-containing mix were heavily rusted and pitted. Corrosion of the steel cylinders was more localized but generally less severe than that of the iron rods.

4.3.6, 6.2.2, 3.5.9

**A Surface Reaction Between Aluminum Monofluoride and Iron at Elevated Temperatures.** (In German). ARMIN SCHNEIDER AND WERNER SCHMIDT. *Z. Metallkunde*, **42,** 73-75 (1951) Mar.

Shows the possibility of forming, from aluminum monofluoride adherent diffused layer of aluminum on heated iron, consisting mostly of chemically resistant aluminum trifluoride which is several times as hard as iron. High-temperature atmospheric corrosion tests with aluminum trifluoride-coated iron gave excellent results. Graphs, photomicrographs, and references are presented.—BLR. 4959

4.3.7, 6.5

**Handling Liquid Hydrogen Sulfide.** W. O. BICE, F. PRANGE AND R. E. WEIS. Phillips Petroleum Co. *Ind. and Eng. Chem.*, **44,** No. 10, 2497-2500 (1952) Oct.

Liquid hydrogen sulfide surge tank is constructed of fire-box quality steel of ASTM specification A-70. Corrosion problems with carbon steel in service with anhydrous hydrogen sulfide have not been severe. Such copper alloys as Admiralty brass and antimonial-Admiralty metal show fairly good resistance to hydrogen sulfide corrosion, as do aluminum, Stellite, Inconel, Ni-Resist, and 304 and 316 stainless steel. Aqueous hydrogen sulfide is much more corrosive than anhydrous hydrogen sulfide, and the various metals act differently in the two media. Embrittlement failures have been experienced in valve trim and in Bourdon tubes made of carbon steel and Type 304 stainless steel. Type 316 makes satisfactory Bourdon tubes.—INCO. 5400

## 4.4 Chemicals, Organic

4.4.3, 6.1

**Extractive Distillation of High-Purity Aromatics.** C. L. DUNN AND G. E. LIEDHOLM. Shell Development Co. Paper before A.P.I., Midyear Mtg., San Francisco, May 1952. *Oil & Gas J.*, **51,** No. 5, 68-70, 96 (1952) June 9.

Discussion of the application of Shell Oil Co.'s new process for the production of nitration-grade aromatics, benzene and toluene, and how the problem of maintaining product purity is met. The process consists of 3 steps, one being distillation in the presence of phenol. Most of the equipment in phenol service is of carbon steel except in some cases where Type 316 stainless and Worthite are used. One table lists the effect of temperature on the corrosion of steel by phenol and another gives the corrosion rate of different alloys in phenol service. Alloys include carbon-steel, 12%-chromium steel, 18-8, Durimet stainless steel, 24-20, nickel and aluminum 2-S. Diagram and tables are given.—INCO. 5471

4.4.5, 6.4.2

**Corrosion of Aluminum by Carbon Tetrachloride.** M. STERN AND H. H. UHLIG. Massachusetts Inst. Technology. *M. I .T. Quarterly Rept.*, **2,** No. 3, 36 pp. (1951) July 1—Sept. 30.

When aluminum was exposed to boiling carbon tetrachloride, an induction period existed before reaction occurred. This delay increased with dissolved water, carbon disulfide, or oxygen in the carbon tetrachloride, and decreased in the presence of corrosion products. The corrosion rate, after the induction period, was very high and was doubled in water-saturated solvent. Oxygen, nitrogen, and corrosion products have no practical effect on the rate whereas hydrochloric acid increases it by 35%. The induction period for aluminum alloys was greater than for high purity aluminum and the long-time corrosion rates are usually lower than for pure aluminum. This fact, combined with negligible effects of galvanic coupling or of an applied potential of 1.5 volts, suggests that direct chemical reaction occurs. Diagrams, tables and graphs are included. 15 references.—INCO. 5060

4.4.5, 6.4.2, 3.2.3

**Effect of Oxide Films on the Reaction of Aluminum with Carbon Tetrachloride.** M. STERN AND H. H. UHLIG. Massachusetts Inst. Technology. *M. I. T. Quarterly Rept.*, **2,** No. 3, 18 pp. (1951) July 1—Sept. 30.

Attempts to improve the protective film on aluminum by anodizing resulted in some extension of the induction period, but not to a practical extent. This was true whether anodized coatings were produced in ammonium tartrate or sulfuric acid electrolytes. The natural film forming on evaporated aluminum was more protective over long periods of exposure than either the anodized or heated films, but these, too, could be damaged by scratching either during or before exposure to boiling carbon tetrachloride. The superior resistance of some aluminum alloys to boiling carbon tetrachloride is probably not related to an oxide coating but rather to a protective film of another kind. Graphs and tables are included. 2 references.—INCO. 5059

4.4.7, 1.6

**Performance of Lubricating Oils.** H. H. ZUIDEMA. 179 pp., 1951. Reinhold Publishing Corp., New York.

This book, containing numerous charts, tables, and illustrations, summarizes and evaluates available data on performance characteristics of lubricating oils under various conditions. The subject is approached from the point of view of performance, rather than specific application. Chapters are devoted to such topics as the lubrication process, flow characteristics, sludge and lacquer deposition, bearing corrosion, emulsification and foaming, viscosity, pour point, and extreme-pressure lubrication. A chapter on manufacturing methods is designed to point out the effects of each step in the manufacturing process upon the performance characteristics of the final product.—BTR. 5182

4.4.7, 6.3.8, 3.4.6

**The Role of Peroxides in the Corrosion of Lead by Lubricating Oils.** B. S. WILSON AND F. H. GARNER. *J. Inst. Petroleum*, **37,** 225-238 (1951) May.

An investigation was undertaken on the corrosion of lead by lubricating oils undergoing oxidation at an average temperature of 150°C. Methods were devised for the determination of acid contents of the oils, the determination of peroxide content of the oils, and the rate of corrosion of lead. High-temperature oxidation of white oils and engine oils produced peroxides and acids. The peroxides, in conjunction with the acids, are capable of producing corrosion of pure lead in the absence of atmospheric oxygen. Provided that appreciable acidity has been developed, the rate of corrosion is independent of acid concentration. but dependent on the peroxide content, as no corrosion took place in the absence of peroxides. In the presence of acids and peroxides, the rate of corrosion is considerably influenced by the presence of atmospheric oxygen in the oil; atmospheric oxygen, in conjunction with the peroxide content, controls the rate of corrosion. For the engine oils, the concentration of atmospheric oxygen had the greater influence, and for the white oils the peroxide concentration had the greater influence. The work has shown the importance of peroxides and atmospheric oxygen in the mechanism of corrosion, thus supporting the theory that the metal is oxidized before reacting with the acids. 5215

4.4.9, 6.2.5, 3.5.3

**How Equipment Adaptability Aids Preventive Maintenance.** F. L. BRADLEY. Forstmann Woolen Co. *Power Eng.*, **56,** No. 5, 82 (1952) May.

Coal feeder system developed difficulties with wet coal in the pipe between the bunker and coal scale and the discharge pipe from the scale. The flow was impeded as corrosion of the steel platework developed surface roughness. This was replaced with stainless steel whose resistance to corrosion from wet and high sulfur content coals made it desirable for long life. Its smooth surface eliminated the main coal feeding problem. Diagrams.—INCO. 5402

4.4.9, 8.4.3, 6.2.1

**Sulfur in Fuel Oils.** P. F. SCHMIDT. Allied Oil Co., Inc. *Power Eng.*, **55,** No. 2, 96-97 (1951) Feb.

Effect of sulfur in fuel oils and methods of testing for sulfur are discussed.

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Maximum sulfur limits are specified and the corrosion due to sulfur is discussed in detail. Discussion includes method of testing, sulfur contents of different grades, maximum sulfur limits, corrosion due to sulfur, and sulfur limits for steel mills.—INCO. 5250

## 4.5 Soil

4.5.1, 3.3.4

**The Battle Against Corrosion.** Trevor J. Williams. *Australasian Engr.*, May 7, 1951, 149+.

Corrosion has been proved to be due to the action of sulfate-reducing bacteria. These microbes have the power of converting certain salts in the soil to sulfureted hydrogen. Various methods of cure are proposed.—MR. 5247

4.5.3, 5.2.1

**Potential and Current Requirements for the Cathodic Protection of Steel in Soils.** W. J. Schwerdtfeger and O. N. McDorman. *J. Res. Nat'l. Bur. Standards*, 47, No. 2, 104-112 (1951) Aug.

Potentials of steel in 20 air-free soils varying in pH from 2.9 to 9.6 were determined in the laboratory. These data and the potential pH relation for the hydrogen electrode were used in fixing the optimum potential for the cathodic protection of the steel against corrosion. The effectiveness of this potential for the cathodic protection of steel in soils was confirmed by weight-loss measurements on electrodes that were maintained at the selected potential in five corrosive soils. Cathodic polarization curves are interpreted in terms of the potential and current requirements for the cathodic protection of steel in soils. 10 illustrations, 4 tables.—TDD. 4981

## 4.6 Water and Steam

4.6.1

**Corrosion by Water.** American Chemical Society (Division of Water, Sewage and Sanitation Chemistry). *Ind. and Eng. Chem.*, 44, No. 8, 1736-1795 (1952) Aug.

Symposium, including the following papers: "Corrosion Control in Water Systems," H. H. Uhlig (covers cathodic protection, metallic and organic coatings, inhibitors, etc.); "Cooling Water Problems in the New York Metropolitan Area," S. Sussman; "Effects of Velocity on Corrosion by Water," H. R. Copson (general effects, effect on corrosion of iron, zinc, copper, copper alloys, cavitation, erosion); "Effect of Temperature on Corrosion of Metals by Water," N. Hackerman (both individual metals and metallic couples); "Corrosion Control with Organic Inhibitors," J. N. Breston; "Inhibitors for Eliminating Corrosion in Steam and Condensate Lines," R. C. Ulmer and J. W. Wood (mild steel, copper, 60/40 brass); "Action of Sodium Silicate as a Corrosion Inhibitor in Water Piping," L. Lehrman and H. L. Shuldener (plain and galvanized iron, brass); "Protection of Metals against Pitting, Tuberculation, and General Corrosion: Combined Phosphate-Chromate Treatment," H. L. Kahler and P. J. Gaughan (steel, cast iron, Admiralty metal); "Protective Film Formation with Phosphate Glasses," G. B. Hatch (couples of steel with stainless steel, gold and platinum); "Inhibition of Galvanic Attack of Steel with Phosphate Glasses," G. B. Hatch (copper/steel, zinc/steel and copper/zinc couples); "Cathodic Protection of Steel in Contact with Water," L. P. Sudrabin and H. C. Marks (fundamentals; effect of dissolved oxygen, temperatures, velocity, water compositions, and coatings; anode materials); "Pitting Corrosion Characteristics of Aluminum: Influence of Magnesium and Manganese," P. M. Aziz and H. P. Godard.—BNF. 5393

4.6.1, 3.5.11, 1.3

**Effects of Velocity on Corrosion by Water.** H. R. Copson. *Ind. and Eng. Chem.*, 44, 1745-1752 (1952) Aug.

Velocity can be a major factor in the corrosion of metals by water, but most available information on the subject is scattered. A general review, therefore, was undertaken with emphasis on iron, zinc, copper, and their alloys. Pertinent unpublished data are included. Generally, corrosion increases with velocity, but the effect may be just the opposite. Motion may sometimes eliminate and sometimes cause local attack. It may have a marked effect on galvanic couples. At high velocities mechanical damage accelerates attack by erosion corrosion and cavitation erosion. Experience and a detailed knowledge of operating conditions are essential for the analysis of a particular problem. It is important to be on the lookout for the secondary effects of velocity. 56 references.—NSA. 5377

4.6.2

**Hot Lime Zeolite Proves Practical.** L. F. Wirth Jr. (Nat. Aluminate Corp.) and W. S. Butler (Dow Chemical Co.). *Power*, 95, No. 3, 110-113+ (1951) Mar.

Dow Chemical Co. at Ludington, Michigan, reports on these advantages: simplified chemical control, improved silica removal and lower primary softener turbidities, positive hardness reduction by ion exchange and minimum carbon dioxide in steam. The Composition Comparison table summarizes the operating experiences of the evolution from Condition A, hot lime-soda softening followed by phosphate softening to Condition E, the final hot-lime sodium-aluminate softening with sludge blanket followed by hot-styrene-resin exchange softening. Colorometric test for magnesium is included. Table.—INCO. 5231

4.6.2, 5.7.7, 5.7.1, 8.2.2

**Accurate pH Control Eliminates Corrosion.** Myron L. Crater, Chief of Steam Plant Engineer, Public Service Department, City of Glendale, California. *Power*, 96, No. 10, 78 (1952) Oct.

In the two years that condensate pH has been accurately controlled at the City of Glendale 40,000 kilowatt Steam Electric Plant, there have been no indications of significant corrosion in the condensate system.

Oxygen can be eliminated by deaeration and the use of catalyzed sodium sulfite while an amine type treatment is used to counteract another corrosion factor, carbon dioxide. Dosages of amine are regulated to maintain a condensate pH between 7.2 and 7.6 as indicated by a Beckman automatic pH indicator in connection with a Bailey circular recorder.

The author reports a reduction by a factor of 10 in the amount of amine used with accurate pH control.—NALCO. 5403

4.6.2, 7.2, 6.2.1

**Steam Pipe Materials for Advanced Steam Conditions.** D. W. Crancher. Paper before Inst. Marine Eng., May 1952. *Trans. Inst. Marine Engrs.*, 65 (1952) July, Ann. Steam Number, 278-282.

Consideration of materials for use in upper limits of steam conditions (800-950°F, with experimental installations operating up to 1050°F). Recapitulation of creep data on plain carbon, low-alloy molybdenum and molybdenum-vanadium steels, with comments on suitability of the steels for various conditions of service is made. Short note on chromium-molybdenum steel is included. Creep properties of 18-8 and molybdenum-vanadium steels are compared. Type of corrosion encountered in steam service, review of published data on behavior of alloy steels, welding and preheating practice, and practice in U. S. in use of molybdenum, chromium-molybdenum, and 18-8 steels in upper limits of steam conditions are given.—INCO. 5411

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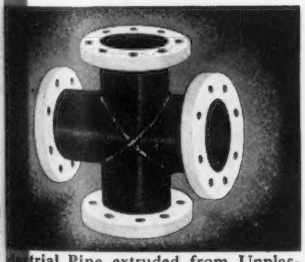

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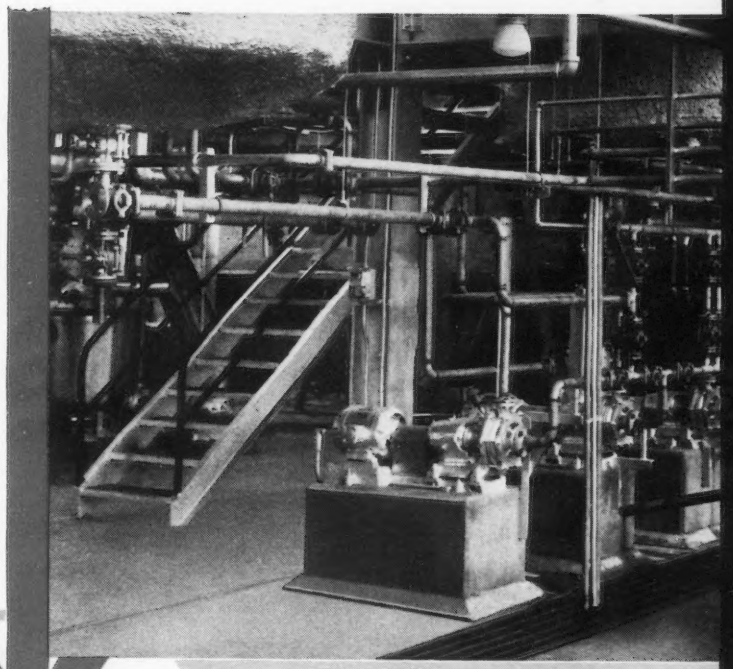

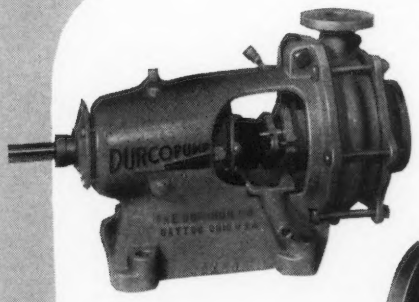


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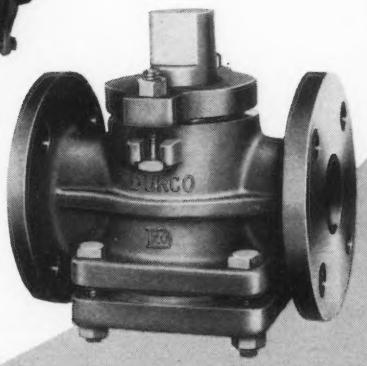


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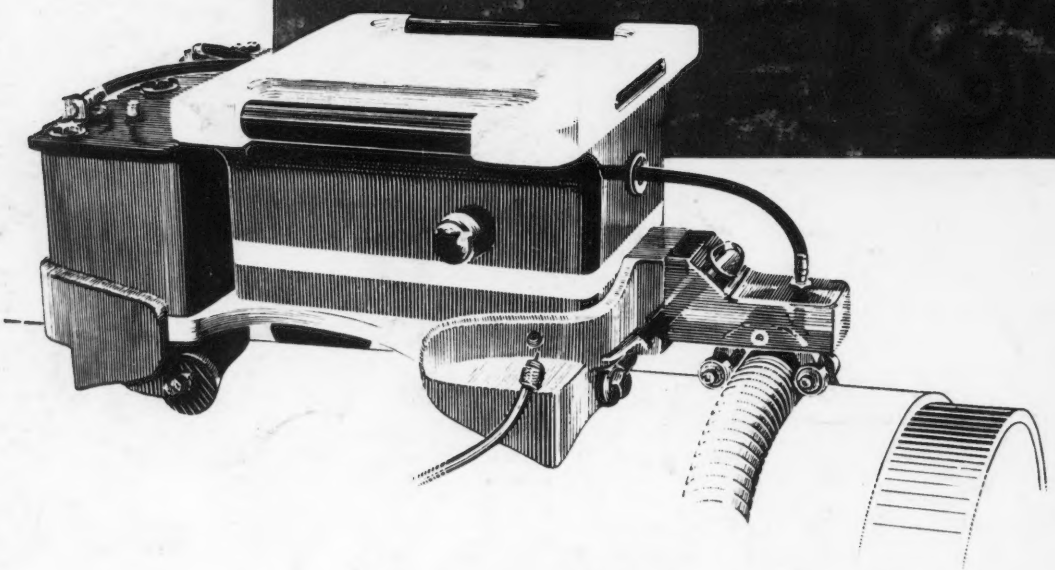

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